COST FP1302 WoodMusICK

2nd Annual Conference

EFFECTS OF PLAYING ON EARLY AND MODERN MUSICAL INSTRUMENTS

Royal College of Music, London

September 9-10, 2015

Proceedings

Editors: Gabriele Rossi Rognoni & Anna Maria Barry

Organised by:

ROYAL COLLEGE OF MUSIC London

WoodMusICK FPS COST Action FP1302

ISBN: 978-84-946352-5-0

DOI: https://doi.org/10.3926/wm2015

Printing and Binding: OmniaScience (Omnia Publisher SL) | www.omniascience.com

Cover Design: M. A. Pérez. Antonio Torres guitar fretboard.

Printed in Barcelona

EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

COST is supported by the EU Framework Programme Horizon 2020

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A sincere thank you to all of the RCM staff who have been involved in the organisation of this conference; particularly the Departments of Estate, RCM Studios, Marketing and Communications, Box Office, Finance, Performance and Programming, Reception and Facilities, the Heads of undergraduate and postgraduate programmes, and the Head of Historical Performance.

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Effects of Playing on Early and Modern Musical Instruments

Aside from a few exceptions, musical instruments are very efficient tools, designed and built with the aim of combining the best musical result with ergonomic and economic considerations. However, as with many tools, their durability is closely connected to high structural tension, the reaction of materials to wear, chemical and humidity changes, and many other technical issues. The situation is further complicated by cultural expectations to experience the sound of musical instruments both passively and actively, regardless of their age.

It is sometimes the case that some instruments, for example those of the violin family, are used almost continuously for three hundred years or more. Their cultural appeal goes far beyond consideration of their sound, eventually leading to the idea that use is vital for their long term conservation. On the other hand there exist instruments, particularly from the keyboard or woodwind family, which have been restored to playing condition after long periods of rest due to an increased interest in performing early music on original instruments over the course of the twentieth century. Conversely, other instruments are considered too fragile to be used and are therefore preserved for their cultural and aesthetic value, sometimes being used as models for the creation of functional copies. In all these cases, issues arise with regard to the effects of use and the choices of makers, the taste of performers, as well as with changing conservation policies and techniques: how is sound affected by continuous use; what effects does it have on the short and long term conservation of the materials; how does this affect decisions concerning modern replicas; and how can preventive techniques help to minimise risks connected to use and improve musical performance?

Issues related to the use of instruments are also a primary concern for contemporary makers (both historical and present day) who are continuously experimenting with new materials and practical techniques in order to improve the performance and resilience of newly constructed instruments. While there are several elements that guide the choice of materials and working techniques, the reaction of the instrument to performance under a variety of conditions is certainly one of the leading factors. How do traditional and innovative materials react to playing? How much are cultural choices led by issues related to performance? How does the choice of different materials affect the performer and the audience?

This conference aims to broadly address the implications of playing on original and contemporary instruments and on replicas, with particular attention to:

- Historical and contemporary approaches to the choice of materials in musical instrument construction and the implications of such choices for performance.
- Monitoring and predicting the short and long term reactions of instruments to being played/not played.
- Acoustical and perception analysis of early musical instruments in action, also in comparison with replicas.

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Perspectives from a Changing Culture: One Hundred Years of Debate on the Role of Musical Instruments

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> 'Violins kept in vitrines dry out and die. It is the use and the humidity emanated by the player that keeps them alive'. (Lorin Maazel, *The New York Philharmonic in Victorian New York*, 6th December 2002)

> 'Instruments by continual use are apt to become weary. They may even virtually be killed. Give them rest. We feel it a duty to urge most strongly that fine instruments should not be brought to premature death by ceaseless use' (W. Henry, Arthur F., Alfred E. Hill, *Antonio Stradivari: His Life and Work (1644-1737)*, 1902, p. 239)

> '[The musician's] task is to consume musical instruments'. (*CIMCIM Bulletin* 50, 2002)

These three powerful quotations, spanning a period of a hundred years, epitomise effectively the extremes of current perceptions on the topic of this conference: although their assumptions and conclusions are quite contrasting, they generally agree on the fact that usage plays a key role – vital or deadly as it may be – on the 'life' of musical instruments. But the span of opinions on the effects of playing on musical instruments is so wide, even today, to characterise this as one of the most urgent areas for collaborative research in the field of musical heritage.

The relationship between use, wear and tear, and acceptable maintenance is one of the most complex concerning any functional object – be it old or new – and plays a key role in decisions relating to its design, choice of materials and construction. However, it is historically accepted that a certain number of invasive interventions will be part of common maintenance during the active life of most of these objects: as early as 1676 Thomas Mace highlighted how, in order to keep a lute in good working order, it might be necessary to remove its soundboard every one or two years (Mace 1676, 2:54), and systematic records of conservation required to maintain bowed and keyboard instruments in playing condition survive for example in the Medici collections from the 16th century (Montanari 1997). It is only well into the second half of the 19th century that the idea of 'originality' begins to be applied to musical instruments and considered a quality. By then, as Carl Engel points out in 1870, 'unimpaired specimens of some kinds are, indeed, now rarely met with' (Engel 1870, 64).

The new enthusiasm for early music and performances on period instruments that characterised the first half of the 20th century, however, was stronger than most concerns about originality and conservation of historical evidence, and it was only in the late 1960s that this began to be perceived as a serious issue (Berner, van der Meer, and Thibault 1967). Meanwhile, organology – the study of musical instruments – grew dramatically as a discipline and the interest in earlier modifications, transformations and repairs began to be understood and studied as evidence of the long active life of instruments.

The study of the modifications that instruments underwent in the course of their life is sometimes more interesting as an area of study than the instruments themselves, and this is because – often more than with any other type of cultural heritage – many instruments underwent a comparatively long life of active use, and a use that relates to an aspect of culture that is otherwise very difficult to document until the beginning of the age of recording: music making. The ways in which musical instruments were used, and the way that these changed, often offer a key perspective to reconstruct changes in music performance and taste that would be hard to substantiate otherwise. Keys being added and moved in keyboard instruments, strings and keys added to plucked and woodwind instruments, repairs, patterns of wear, and layers of transformation, all tell stories – musical stories – that the collaboration between museums, musicians, conservators and scientists has been helping to unfold. The results of this approach, whose potential was individuated already in the late 19th century, have become particularly convincing in the past decade, but it is clear that we have only yet scratched the surface.

Two elements appeared between the end of the 19th century and the mid-20th that added a new perspective to the issue: the appearance and growth of public musical instrument museums on the one hand, and the spreading success and interest towards the revival of early music on the other. The combined effect of these two elements led to an increasing number of musicians borrowing and bringing old instruments 'back to life' (an oft repeated expression) for performances and recordings. These instruments were often from museums and public collections. Unfortunately the results were often disastrous because of the combination of limited experience and understanding of these instruments on one side, and the fact that most of them needed to be restored to playing conditions after an interruption in some cases of several centuries.

This added a new dimension to the issue of using musical instruments, or in fact extended to all types of musical instruments an issue that until then had been mostly confined to those of the violin family and church organs: the effects of playing on old musical instruments – with or without an uninterrupted tradition of usage – became a new area of concern: only around this time papers and publications began to focus on the effects of playing on musical instruments, how some of the worst ones could be reduced, and which good ones could counterbalance the others (van der Meer 1964; Montagu 1974; Day of Study on the Restoration of Stringed Instruments 1976; Abondance 1981; Ferrari Barassi and Laini 1985; Restauro, Conservazione e Recupero di Antichi Strumenti Musicali). Time cannot be stopped, but what accelerates the decay of our instruments, and what does not? (A question, by the way, which applies just as well to modern instruments as to old ones).

If we follow the discussion through some of the milestones in conservation literature, we obtain a clear perspective of the gradual increase in the awareness and concern about the use of early instruments in the past 50 years: in the first specialised monograph on 'Preservation and Restoration of Musical Instruments', edited by Alfred Berner, Jack van der Meer and Geneviève Thibault in 1967, we hardly find any mention of what happens to a musical instrument after it is brought back to play. It is assumed that western instruments, with few exceptions, are going to be restored to playing conditions if they are inefficient, and the issue to be discussed is 'what is acceptable to reach this goal'. Subsequent consequences seem still very much to be discovered.

As a consequence, the following two decades saw an uproar of interventions on musical instruments, often by reputed and leading conservators, some of whom now look back at their work of that time with some regret. By the early 1980s this had led to a more rounded perception of the importance and complexity of musical instruments as cultural heritage. Some collections, particularly the Vleeshuis Museum in Antwerp and the Royal College of Music Museum under the guide of Elizabeth Wells began experimenting with the making of copies for conservation purposes, a solution that has the great merit of diverting the consequences of use from the original to a reproduction, but that for obvious reasons can only be applied to an infinitesimal fraction of the instruments that are in use – for cost and space reasons – and that is also only partly satisfactory in eliciting the reactions that an original instrument triggers in both the player and the audience. A parallel study of originals and their copies, aimed at assessing the similarity or diversity of wearing patterns and consequences of use, could potentially lead to a better understanding of wearing dynamics and of the usage history of originals, but I am not yet aware of any study where this approach has been systematically applied.

In the same years, authors such as Florence Gétreau, John Barnes and Bob Barclay were advocating a more careful approach, and for the first time trying to assess wear and tear as part of the life of an instrument both new, or after restoration, whenever it was used (Abondance 1981; Barnes 1980, Barclay 2005). Attention at this point was very much focussed on what we can call 'macro consequences' of usage: the wear caused by the repeated action of the musician's fingers, the scratches of plectra on plucked instruments, the wear of wood around finger-holes in woodwinds, the traces left by chin-rests, or by the bare skin of the musician on violins and violas, the physical deformation of soundboards under the tension and pressure of strings, the effect of humidity, the wear of parts due to frequent cleaning, the mechanical wear of parts against parts.

John Barnes even suggested some countermeasures to limit the wear of keyboard instruments being used: 'a restored keyboard instrument should have a suitable material covering the key-plates, […], and perhaps a thin plastic membrane protecting some of the soft action parts' (Barnes 1980, 218). I never heard of this suggestion to have been applied, but it is clear that – although sound and musical efficiency remained a priority – countermeasures were being studied to reduce the impact of work on historical instruments.

Coming back to our times, we can say that practice, through the careful activity of musicians, museums and some conservators, has led us to a rather accurate understanding of many of these macro-effects, although much remains to be investigated regarding ways to document, reduce and contrast these issues (R. L. Barclay 2005): we all know that key-plates wear down with use, as well as varnishes and materials in general, but how can we measure and document these changes, can protections be used that do not in any way modify the original surfaces and materials, and have no impact on sound? Even measuring the simple change in colour of a violin exposed to light is a major challenge, let alone the documentation of the complex and numerous macro-phenomena that occur, for example, on a 17th century harpsichord regularly played in concerts over a period of several years. This is a major area where the help of scientists is badly needed if we want to move forward from assumptions that by now are more worn down than the instruments under discussion.

However, these are only some of the issues on which collaboration between scientists, conservators and curators could lead to new practices and understanding. The most complex issues, and those around which our knowledge is still completely inadequate, are those that could be defined as micro- and long-term effects: these began to be considered systematically only in the last couple of decades and although knowledge in material science has immensely progressed in recent years, their specific consequences on musical instruments are still almost unexplored. In the words of an influential group of conservators writing in 1997: 'Wear with use may be obvious and require continual attention, or it may be difficult to detect over a period of days, weeks or months, and only become significant, harmful and obvious over a period of years' (R. Barclay 1997, 83). Despite the fact that this text is now almost 20 years old, the state of current knowledge is still very much the one that we read in the following pages: 'Unpredictable behaviour makes clear guidelines for using early woodwind instruments impossible to establish' (R. Barclay 1997, 100) and 'too little is known about the behaviour of woods under these conditions to allow adequate guidelines to be presented' (R. Barclay 1997, 101) which leads to the sensible conclusion that 'there are few circumstances under which the woodwinds of a collection can be used' (R. Barclay 1997, 101). But this just means that we need to be exceedingly – and sometimes frustratingly – cautious because we do not know enough. Further research is now vital in order to strengthen the ground on which we make better informed decisions. Although woodwinds are certainly the most obscure area with regard to our understanding of reactions to use, stringed instruments are in no better condition, despite centuries of observation: the behaviour and medium- and long-term reaction of their materials, particularly where sound is concerned, is only now beginning to be systematically documented and explored.

Finally the effort and intensity of debate which arose in museum collections over the past fifty years may immediately lead one to think that the issues which we are discussing are specifically related to museums and early instruments, but I would like to dispute this assumption strongly: for all musicians, musical instruments are extensions of their artistic personality to the point of attributing them characteristics that are eminently human (we often talk about bringing instruments back to life, letting them die or transforming their personality). The long term preservation, or 'good health' of their instrument is for a musician at least as important – often more important – than for most curators. As a consequence of many different phenomena, an increasing number of musicians play instruments that are several decades old and have been subject (and will be subject) to continuous use for hopefully much longer. We can easily assume that the issue of reducing the adverse consequences of use on them is more compelling to their owners than to any museum, considering how more regularly their instruments are going to be played and how much of their personal success relies on them.

Even those who play recently made musical instruments know that they react plastically to the effects of being used, although these reactions are often difficult to describe accurately and correlate reliably with the multitude of processes that affect instrument, musician and eventual audience during any performance. At the same time, the interest of makers for the behaviour of materials and their interactions is obvious and evident through the many experiments that have been undertaken for centuries, and still are one of the most evident aspects of musical instrument innovation.

The complexity of this field is huge and will require coordinated efforts and resources over a long period, but it cannot be denied that it is a major and relevant issue that impacts a great number of people including musicians, their audiences, makers, and conservators, as well as an important part of our cultural heritage, of which instruments (old as well as new) are all a part.

Bibliography

Abondance, Florence. 1981. *Restauration Des Instruments de Musique*. Fribourg: Office du Livre.

Barclay, R. L. 2005. *The Preservation and Use of Historic Musical Instruments: Display Case and Concert Hall*. London ; Sterling, VA: Earthscan.

Barclay, Robert, ed. 1997. *The Care of Historic Musical Instruments*. Edinburgh: CCI - CIMCIM.

Barnes, John. 1980. "Does Restoration Destroy Evidence?" *Early Music* 8 (2):213–18.

Berner, Alfred, John Henry van der Meer, and Genevieve Thibault, eds. 1967. *Preservation & Restoration of Musical Instruments*. London: Evelyn, Adams & Mackay.

Day of Study on the Restoration of Stringed Instruments. 1976. Cremona: The Committee for the Preservation of the National Stringed-Instrument Heritage.

Engel, Carl. 1870. *A Descriptive Catalogue of the Musical Instruments in the South Kensington Museum*. London: George E. Eyre and William Spottiswoode.

Ferrari Barassi, Elena, and Marinella Laini, eds. 1985. *Per Una Carta Europea Del Restauro*. Florence: L.S. Olschki.

Mace, Thomas. 1676. *Musick's Monument; or, a Remembrancer of the Best Practical Musick, Both Divine and Civil ... Divided into Three Parts, Etc.* Vol. 2. London: T. Ratcliffe and N. Thompson, for the Author.

http://hz.imslp.info/files/imglnks/usimg/4/4e/IMSLP104686-PMLP193185-musicksmonumento00mace_bw_2_lute.pdf.

Meer, J. H. van der. 1964. "An Example of Harpsichord Restoration." *The Galpin Society Journal* 17:5–16. https://doi.org/10.2307/841308.

Montagu, Jeremy. 1974. "Nuremburg Conference on Restoration." *Early Music* 2 (4):265–67.

Montanari, Giuliana. 1997. "Conservazione e Restauro Degli Strumenti Ad Arco Alla Corte Di Firenze in Epoca Lorenese (1737-1770)." Liuteria, Musica e Cultura, 3–19.

Restauro, Conservazione e Recupero Di Antichi Strumenti Musicali: Atti Del Convegno Internazionale, Modena, 2-4 Aprile 1982. 1986. Biblioteca / Historiae Musicae Cultores 40. Firenze: L.S. Olschki.

The Effects and Consequences of Playing Historical Keyboard and Stringed Instruments

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Introduction

We will consider the effects and consequences that playing has on the Academy's historical and modern keyboard instruments and stringed instruments of the violin family. The Royal Academy of Music was founded in 1822. The keyboard collection on public display comprises two harpsichords, twelve pianos and the oldest instrument from this collection: a virginal from the early 17th century. The Academy has approximately 150 keyboard instruments available to its students for practice, rehearsal and performances.

The stringed instrument collection comprises nearly 250 examples of its kind. Both collections showcase a wide cross section of examples from various European schools. The Rutson Collection, donated in 1890, contains Cremonese instruments from the 'Classical period', including fine examples from Antonio Stradivari's workshop. The Academy also has the famous Stradivari violin Viotti ex-Bruce from 1709, acquired in 2005 through the ACE/DCMS Acceptance in Lieu Scheme and with the assistance of donors. What is interesting is the way these two categories of instruments have developed. The differences between a virginal, a harpsichord, a fortepiano and a piano, demonstrate how each musical époque 'invented' its own keyboard instrument type. Violins, however, have changed very little and in fact those made between 1550 and 1750 in Italy became the blueprint for all subsequent violins and are still in use today playing contemporary music.

So how has playing impacted these instruments? Some researchers also suggest that playing an instrument changes the cell structure (hemi-cellulose) of the wood and ultimately improves its sound or playing qualities. Other positive aspects of playing include:

- they can be heard
- they are regularly maintained.

Yet over the last few hundred years mint examples of historical instruments have declined in number. So how has playing negatively impacted these instruments? The direct impact of playing has resulted in:

- wear and tear, leading to intrusive restoration
- accidents
- exposure to sudden changes in temperature and humidity
- string tension causing deformation and distortion on keyboard frames and string instrument bodies.

The desire to play instruments also resulted in an indirect impact causing the following:

- conversions, instruments of earlier periods being adapted to requirements of later periods and the use of different strings with higher tension
- 'modernisation' of the instrument to suit the musician's requirements, current trends, commercial considerations (such as alterations in sizes etc.)

Today we value and protect the integrity of musical instruments - our understanding has changed. Alterations to the size of valuable 'classical' Italian cellos or violas were undertaken to increase their market value in the late 1800s, whereas nowadays such alterations would not be undertaken - those done in the past have lowered the market value of the instrument. Little detailed information regarding invasive alterations to historical instruments has been published and therefore much of the information about the making process, the instruments original size, shape, dimensions and varnish has been lost.

Methods

So the key question is how do we assess the actual impact that playing has on these instruments? There are no records to help us assess changes in sound – recordings only go back to the very late 19th century. We can however assess the impact of the alterations in the structure, substrate and varnish that playing has prompted. Detailed condition assessments, documentation, correspondence etc. all help us establish what has been done to the substrates, the keyboard actions and surfaces. Photographs, illustrations and UV light help to compare instruments in mint condition with altered instruments. The Academy's Antonio Stradivari Viotti ex-Bruce 1709 violin serves as an example for an instrument in nearly mint condition.

Results

Playing and handling clearly has an impact on the physical, stylistic and acoustic properties of historical and modern instruments. Consequently we need to review the instruments regularly, monitor access and usage, instruct the potential players, and keep a keen eye on climate control when instruments are in store or on display. Overall, in-depth consultations are now considered to be a key aspect of responsible conservation. An essential role in maintaining the longevity of our musical instruments is striking a knowledge-based balance between playing, maintenance, restoration and conservation.

Discussion

- Even the most careful of playing causes potentially irreversible damage.
- Does this raise concerns about continuing to play the remaining, rare fine instruments?
- Will they effectively become extinct?
- To what extent should we allow access and where do we strike a balance between overprotecting and overusing the instruments?
- But what happens if they never get played – does that preserve them sufficiently or do we think they need occasional careful playing to not lose their voice?
- Underpinning all of these questions is how do we actually measure damage?
- To what extent have the playing qualities been affected by invasive restoration?
- Could the unproven but widely held belief that old instruments are ´better´ than contemporary ones be successfully challenged, such that the use of ´fine´ contemporary instruments may be one alternative to protect the 'fine´ old ones from further use and deterioration?
- Setting up a carefully guided project, using academy instruments, that 'analyses' their sound quality in all its parameters over a number of years or decades could be one way of obtaining useful insight into how an instrument changes when it is played.

Acknowledgements

Thank you to Peter Bavington, Ian Brearey, Angela Doane, Christopher Nobbs and Elizabeth Wells.

Bibliography

A comparison of Wood Density between Cremonese and Modern violins [C.S.Berend, T.M. Borman, *PLOS* July 2008]

Conservation, restoration and repair of Stringed Instruments and their Bows, Volume 1 [Ipci Canada, Montreal 2010]

Evolutionary Road, Part 1 and 2 [Roger Hargrave, Strad, February 2013, p.54-63, March 2013, p58-46]

Some aspects of Wood Structure and Function [Ephraim Segerman, *Catgut Acoustical Society Journal*, 2001]

Playing on Old Stringed Keyboard Instruments in the Museum Vleeshuis

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Museum Vleeshuis, Antwerp, Belgium

In the 1970s, several old stringed keyboard instruments in the Museum Vleeshuis were restored with the explicit intention to play them again. This framed perfectly the philosophy of the early revival of historical keyboard instruments. The former museum director and the teacher of historical keyboard instrument performance at the local conservatory both played a dynamic role in the decisions taken during this time. Five instruments of the collection were made playable: three Antwerp harpsichords (Johan Daniel Dulcken, 1747, Jacobus Van den Elsche, 1763 and Joannes Petrus Bull, 1779), an Antwerp virginal by Johannes Couchet (1650) and a Viennese grand piano by Conrad Graf (1826). These instruments soon became important to the image of the museum, which hereafter in musical circles was mainly associated with old keyboard instruments. The instruments were extensively used, not only for concerts and recordings, but also for education - even as tools for practice for students.

After ten to fifteen years, the condition of the harpsichords deteriorated. Some instruments were no longer allowed to be played. The pianoforte was seriously damaged during a recording in those years. Since then, the Van den Elsche and the Bull harpsichords have not been played. The Dulcken harpsichord has been subjected to new interventions, and the Graf fortepiano has been restored again. Meanwhile, the Couchet virginal became rather problematic as concerns tuning and stability. However, until ca. 1999, musicians continued to play this instrument. In 1999, the new museum director found major damage on the virginal, and decided that playing must be completely stopped. A CT scan showed massive damage inside the instrument. This damage cannot be restored because, during the restoration in 1970, all the parts were glued together with epoxy resin. Even parts that had never been glued were subjected to this treatment. Since then, the instrument is no longer played.

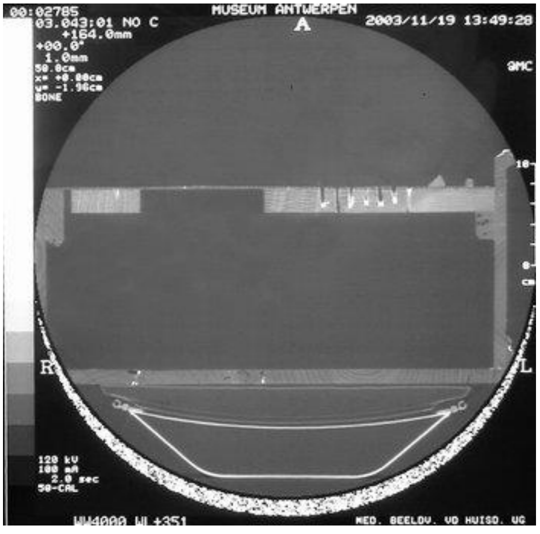

Figure 1: CT scan of the Johannes Couchet virginal. Cracks in the pinblock.

In the winter of 2003 the Dulcken harpsichord's bottom board, which had been renewed during the restoration in 1972, cracked as a result of sudden extreme drought. This triggered a new thorough restoration in 2004-05. Shortly after there was a new rupture in an old glue joint in the inner structure of the Graf fortepiano. This led to a new thorough restoration between 2007 and 2012. Since then, two stringed keyboard instruments are still frequently played: the Dulcken harpsichord and the Graf piano. However, due to the successive interventions since 1972, many important parts are no longer original.

Figure 2: Grand piano Conrad Graf, Vienna 1826.

The use of these instruments is very ambiguous. Since the latest restorations, both the Dulcken harpsichord and the Graf piano are considered to belong to the best sounding instruments of their kind. Numerous musicians ask permission to play both instruments. The two instruments do not belong to the museum, but are a part of a permanent loan from the Conservatory, their owner. The conservatory demands that both instruments are played.

On one hand, the beautiful sound of the two instruments presents a great added value for concerts and recordings in the museum. On the other hand, the museum realizes more than ever that continuous use is destructive in the long-term. The question is whether the wonderful sound that attracts so many musicians is specific to the historical instrument, or also the result of numerous interventions by the restorers. Are we only enjoying the quality of the original Dulcken and Graf, or also the cumulative effect of the restorers' skills? Perhaps, the creation of good copies could provide a solution to this dilemma.

Preventing the Played Instrument's Suicide

Vera de Bruyn-Ouboter

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Introduction

The entire musical instrument is a combination of both: the physical material and the intangible sound. By existing as a whole, the instrument is destroying itself in the long term. Sound is as important as the instrument's physical material, and should be documented and experienced. But producing sound means risking the loss of physical material. Over decades and centuries, there might be little left of the primary parts but a strongly restored and fragmentary instrument. This is not what museums aim to do, according to the rules of ICOM and the conservation code of ethics (ECCO). Musical instruments in collections that are defined as objects with high preservation value underlay various requirements in preservation. There are restrictions for use with the aim to inhibit their ageing processes and all kinds of changes to their materials. In the following abstract these processes are defined; a Risk – Gain analysis for the risk of damage by use is presented; and suggestions for further research into reducing the risks are made.

Forces and mechanical stress

All instruments with membranes and strings kept in playing condition are exposed to force and mechanical stress: membranes on drums or membranes on non-European stringed instruments, all types of instruments of the violin family, guitars, harps and keyboard instruments. Looking closer at historic keyboard instruments, a regularly strung six octave fortepiano bears the weight of a full-grown male elephant [Michal Latcham, 2000]. Over time, due to the degradation of the material itself caused by the previously mentioned influences, this stress will lead to the collapse of the wooden structure. Typical damage is, for example, a deformed wrestplank which has been pulled inwards by the stress of the strings. The functionality of the hammer action is therefore reduced.

Another example is the development of cracks around the tuning pins in the wrestplank which make the instrument impossible to tune and play. A third form of damage is a deformation of the soundboard, pressed down by the strings on the soundboards bridge. The deformation can go so far that the bridge does not function any longer as boundary to the diapason. The instrument is not playable any longer. This kind of deformation, cracking and tearing can be found on all organic materials exposed to strain over a long time.

Figure 1: Bridge of bone on an Indian stringed instrument deformed and cracked by the tension of the strings (Esray.) RMT 67/83, Ringve Music Museum.

Beside stress on stringed instruments or instruments with a membrane, the mechanical strain caused by the musician is a factor which effects all musical instruments being played. Parts reduce themselves in contact to other parts in the form of abrasion by friction. Hand contact from the musician (with acidic PH content of sweat) causes chemical changes in varnish and other materials on the surface.

Other weakening influences

Beside losses caused by playing, the instrument's material combinations attached to each other can develop chemical reactions. Aging processes are accelerated by excessively low, high or changing humidity; light and UV; temperature; or content of gasses in the environmental air. Resulting in degradation processes, like corrosion of metal or the breaking up of molecular chains of organic material like textiles, the materials become brittle, less elastic and more susceptible to damage.

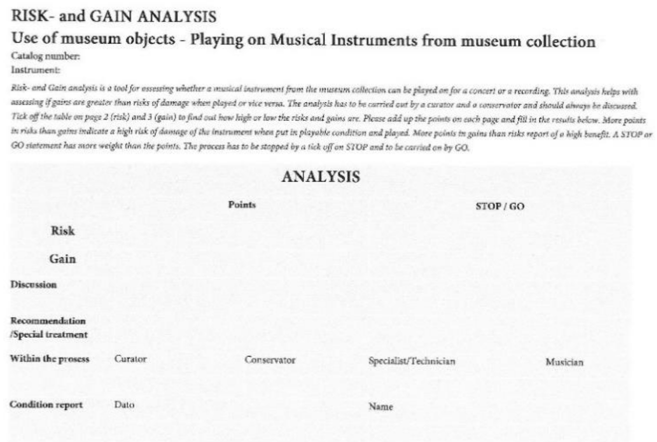
Figure 2: Corrosion of metal in contact with sour leather. Original silk winded strings on a harp piano. RMT 390, Ringve Music Museum.

In wind instruments the humidity and temperature of the musician's breath causes big changes in the molecular structure from the inside, stressing and making them less elastic. All of these kinds of damage have been well known for many years. There is little possibility of preventing the attended played instrument from stress and mechanical force when the material is weakened by the aforementioned factors. The best possibility of preventing damage is to act consciously and to supervise all decision making regarding the playing of the museum object. An understanding of ongoing physical and chemical processes and risks should be examined in advance.

The Risk – Gain analysis

In connection with a sound documentation of musical instruments at Ringve Music Museum in Trondheim (Norway) 2011, a Risk - Benefit Analysis was developed to hinder damage to the instruments through playing. The analysis aims to compare the condition to what gains might be achieved through an audio recording.

Through this Risk - Benefit Analysis, we try to create a compromise by opening a decision making process tied to individual instruments. As part of the music museums policy, the analysis becomes an important tool for the development of conservation concepts tied to playability. It should always be carried out as a collaboration between curator and conservator, also involving musicians as well as instrument makers and other specialists.



RISK- and GAIN ANALYSIS

Use of museum objects - Playing on Musical Instruments from museum collection

Catalog number:

Instrument:

Risk- and Gain analysis is a tool for assessing whether a musical instrument from the museum collection can be played on for a concert or a recording. This analysis helps with assessing if gains are greater than risks of damage when played or vice versa. The analysis has to be carried out by a curator and a conservator and should always be discussed. Tick off the table on page 2 (risk) and 3 (gain) to find out how high or low the risks and gains are. Please add up the points on each page and fill in the results below. More points in risks than gains indicate a high risk of damage of the instrument when put in playable condition and played. More points in gains than risks report of a high benefit. A STOP or GO statement has more weight than the points. The process has to be stopped by a tick off on STOP and to be carried on by GO.

ANALYSIS

		Points		**STOP / GO**
Risk				
Gain				
Discussion				
Recommendation /Special treatment				
Within the prosess	Curator	Conservator	Specialist/Technician	Musician
Condition report	Dato		Name	

Figure 3: First of three pages of the Risk – Gain analysis scheme.

Research needed for the Risk assessment

The Risk – Gain analysis is based on a condition report with a detailed examination of the stability of the individual materials and the instruments functionality. By going into detail the risk of damage and alteration by playing has to be estimated. On this point there is sometimes need for research with other specialists. In the following these examples:

- How can the risk of collapsing and deforming before raising force and tension be measured? An easily usable method for measuring/calculating tension and stress in a complex mixed materials musical instruments construction is needed.
- Material combinations which have developed chemical interaction are constructive weak points. Are those metal parts weakening through corrosion? How can these be stabilised before playing?
- Can the sublimating solid Cyclododecan (developed for intermediate stabilisation of flaking painted surfaces) be used as an intermediate treatment on the inside of a flute before exposing it to human breath? Or is there a possibility of developing a better fitting product?
- Answers to these and more questions can help to improve the Risk – Gain Analysis and to prevent the played instruments' suicide.

Acknowledgements

My acknowledgements go to my colleagues Mats Krouthén and Daniel Papuga, both curators at Ringve music museum, who were part of the development of the Risk – Gain analysis. An inspiring presentation at CIMCIM in 2002 by Corinna Weinheimer gave a basic summary of all damages which can occur on musical instruments by playing.

Bibliography

Michael Latcham, *The Stringing, Scaling and Pitch of Hammerflügel built in the Southern German and Vienneses Traditions 1780 - 1820*, Vol II, p. 146, Musikverlag Katzbichel, 2000

Recommendations for Accessing Musical Instruments in Public Collections: 1985 – 2015

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It is exactly 40 years since CIMCIM (the International ICOM Committee for museums and collections of musical instruments), a component of the International Council of Museums, published a document in which the principal issues that curators of musical instrument collections face every day were elucidated for the first time. Signed by six authorities of different nations and institutions, it was the result of both previous experience and a long debate.

The document started with an announcement: "The task of the museum or public collection is largely twofold: its responsibility for the safety and preservation of its instruments and its goal to further their study and disseminate the information thus obtained. In this manner the museum acts as a link between the craftsmen, performers and scholars of today and their counterparts whose work is represented in the collection." Its content touched upon: conditions of access; general protection from damage; measuring tools and techniques; and, last but not least, "Playing". This last was probably the most remarkable area of discussion, as it came after a long period in which museum instruments were usually allowed to be played, even after this had turned out to be outrageous for many items. It was assumed that "Instruments from public collections should not be allowed to be played for motives of idle curiosity or individual pleasure; nor should they be considered as practice instruments. The use of any museum instrument is connected with a clear risk of mechanical damage". The positions, even though informed by previous damage to the instruments from inattentive usage, turned out in some cases to be unusually constrictive.

Many years thereafter, a new text was published under the advisory assistance of the Canadian Conservation Institute and the editorship of Robert Barclay, with contributions from seven authors (three of them coinciding with those of the previous publication). The new text was affected by the experience developed in the meanwhile, but was substantially based on the same principles: "Present enjoyment is hard to resist, but since a museum artefact is held in trust for the future as well as the present, one should always consider whether a present use or restoration proposal will close off interpretation options for future curators and visitors. No matter how much it may please an influential individual or special interest group today, many of the objects in our care will be viewed and used by future visitors and scholars in ways that are different than those we imagine today. It is, therefore, clear that collections of musical instruments (and other functional objects) provide some problems for museum staff, which differ from those of fine art collections. Nevertheless, their treatment can and should be judged by exactly the same standards applied to treatments of paintings, sculpture, and the decorative arts."

With the increasing number of museums involved in the business, and with varying attitudes related to different experiences here and there, it may seem that curators nowadays are more attentive to the "sound experience" of visitors. However, even today no official distinction is made with regard to two categories of instruments usually left aside from the previous classification: that of organs, and of course of old fine bowed instruments. The first instruments are twinned by historical buildings, whose re-use is forced (at least) by economic reasons. The second constitute a unique case in the field of conservation, being unparalleled by artefacts of any kind, as no other objects are universally expected to be preserved "only" in functioning conditions. This is a case study for further research, which is tentatively affected by the present paper in an unusual way, taking into strong consideration a substantial distinction between public and private heritage.

Bibliography

Recommendations for regulating the access to musical instruments in public collections, CIMCIM, 1985

Per una carta Europea del restauro. ed. by E. Ferrari Barassi, and M. Laini, Florence, Olschki, 1987

The Care of Historic Musical Instruments, ed. by Robert Barclay, Canadian Conservation Institute – Museums

Guitars in Different States

Heidi von Rüden

Musikinstrumenten-Museum, Staatliches Institut für Musikforschung, Berlin, Germany

Old or new instruments – opinions from musicians

To show alterations on 19th century guitars within a period of time, a very detailed documentation is essential. It is seldom a requirement to make an old plucked instrument playable for a concert or a recording. In the museum context the sound we hear is just a provisional arrangement because of several influencing factors. The sound of a guitar can lose its volume and capabilities as some recordings show because the musician has to handle the instrument in a very inauthentic and careful way due to the instability of the guitar.

The Audio recording of the Plucked Instruments in the Edinburgh University Collection of Historic Musical Instruments played by Rob MacKillop in 2003 is such an example. Darryl Martin wrote in the booklet: "…For reasons of integrity it was felt essential to not compromise Rob MacKillop's playing style despite the playing limitations of the instruments…" Another statement about the sound comes from Xavier Díaz-Latorre who played some different guitars from the Collection of the Museum in Barcelona. "They were all in very good shape but they had to be in truly optimum condition to be played in a recording." he wrote. One can hear the differences and imagine guitars in totally different conditions. The catalogue *Faszination Gitarre* attaches a sound document with examples of museum instruments. They were made to guide the visitors through a special exhibition. For this record a Spanish Baroque guitar, similar to a guitar of the Barcelona Collection, was played by Michael Freimuth. On this audio-example we might hear a kind of over caution. The musician has to handle a guitar that is difficult to play because of its poor condition and uncomfortable set-up and string tension. The main point of the restoration was to keep the state of the object and not to reinforce sounding parts. The recording was made to give an idea of the sound and the guitar was made playable for this reason, but not for regular daily use.

Thomas Müller-Pering played the Weissgerber-Guitar Collection of the Museum in Leipzig. He wrote: "I had to calculate into my selection the fact that all of these beautiful museum instruments would only be directly available to me during the time of recording at Schloss Goseck. In view of the sometimes quite unusual shape and scale length of the instruments, their narrow fingerboards and the angular neck profile that is unfortunately rather typical of Weißgerber, this limitation was a handicap not to be underestimated. And so, this project became indeed a challenge of a special kind."

The acoustic component in a documentation of a guitar

At the beginning of the restoration of a guitar the evaluation of arguments for or against actions has to be done very carefully. Sometimes the use of a replica is the best solution to make music audible. In recent years acoustic studies and audible tests have shown that a copy of an old guitar with similar wood and the same sizes of components leads to good results. But the sound of the copy and the original archetype is not comparable by playing both instruments due to one's bad condition, old material etc.

It is important to imply acoustic properties, especially if the sound is of interest. The modal analysis is most suitable to proof alterations which attribute to the playing process.

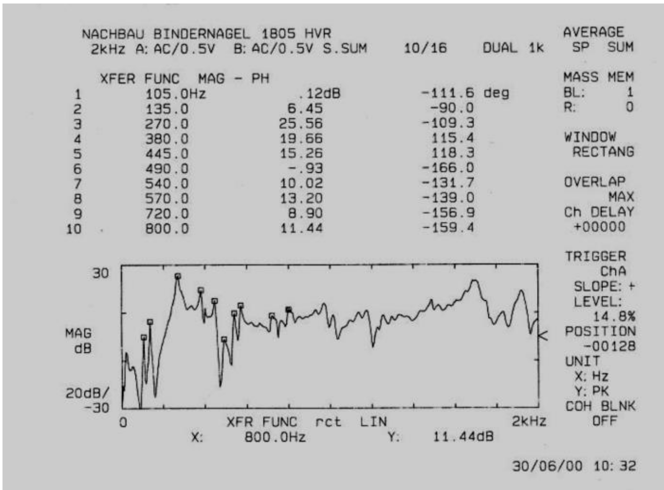

Figure 1: Acoustic spectrum of a copy of a 19th-century guitar by the author

For the measuring set-up a small piezoelectric microphone has to be fixed at the soundboard and a small hammer gives the impulse. The sound of the knocking on the nut of the bridge includes information about the sound of the guitar. It reflects the acoustic characteristics of the instrument. In the example (Figure 1) the acoustic spectrum of a copy of a 19th century guitar has peaks at 105 Hz, 135 Hz, 270 Hz and 380 Hz. All these noticeable frequencies stand for a vibrating part of the guitar. The volume of the guitar body is e.g. quite small and the cavity resonance lies at 105 Hz. Compared to a modern classical guitar it is a high frequency. This means that the sound of the low range, below 105 Hz will not get a great response from the guitar's property. The sound of the first notes on the E-string: E, F, Fis, G and Gis won't be brilliant and rich on harmonic and overtones because there is no space for the development of the sound at this range.

It would be desirable to have an acoustic fingerprint of every instrument, without the necessity of having a playable instrument. When guitars were made in the same way by one maker and they had a comparable good condition, the modal analysis about these instruments show similar courses of the frequency. The University of Applied Sciences in Markneukirchen and other institutions like the IfM in Zwota have operated for years with the acoustic as an objective measurable parameter to report an instrument. They also work with new and historical guitars. They made modal analysis of guitars made in German regions or made by one maker. The collection of study results is not very big yet, but if the method gets a standardized system, the results could be comparable. These measurements could be helpful to identify a maker of an instrument. Today many guitar makers are familiar with a system for measuring the acoustic spectrum and they use it as an interpretation method during the process of building an instrument.

There are some disadvantages about the proposed method. All the acoustic measurements do not occur contact-free and there is always the problem of transport to an experimental set-up which causes most damages. Another advantage could be the invention of a synthetic guitar sound. From a modal analysis we could get a model of all resonances and their special relations from an unplayable guitar; we can modify the data by assembling them with those about notes of a musical piece. Here the movement of the fingers of the right hand will determine sound intensity superimposed as a second layer on pitch. Furthermore it would be possible to use these analysing methods before and after an intensive playing session, to make changes visible. Maybe in future it is possible to create a sound of an instrument in this way.

Bibliography

Bader, Rolf: *Computational Mechanics of the Classical Guitar*, Berlin 2005

Meinel, Eberhard: Akustische Untersuchungen zu Klangeigenschaften von thüringisch-sächsischen Gitarren, siehe Internetseite von Andreas Michel: *Studia Instrumentorum Musicae* 2007:
http://www.studiainstrumentorum.de/MUSEUM/GITARREN/git_sachsen_inhalt.htm [26.02.2015]

Meyer, Jürgen: *Akustik der Gitarre in Einzeldarstellungen*, Frankfurt 1985

Ziegenhals, Gunter: Subjektive und objektive Beurteilung von Musikinstrumenten. Eine Untersuchung anhand von Fallstudien, In: Rüdiger Hoffmann (Hg.): *Studientexte zur Sprachkommunikation*, Bd. 51, Dresden 2010

Ziegenhals, Gunter: Zur Akustik der Gitarre. In: Conny Restle und Christopher Li [Hrsg.]: *Faszination Gitarre*, Berlin 2010, S. 75-86

Audio

Die Weißgerber-Gitarren des Musikinstrumenten-Museums Markneukirchen, Interpret: Christof Hanusch, Autor: Heidrun Eichler, Label: tonus arcus, Markneukirchen 2008

Faszination Gitarre, Hörbuch mit Klangdokumenten, Musikinstrumenten-Museum Staatliches Institut für Musikforschung, Interpreten: Thomas Müller-Pering, Michael Freimuth, Berlin 2010

Gitarren von Richard Jacob Weißgerber (1877-1960) aus der Sammlung des Musikinstrumenten-Museums der Universität Leipzig, Interpret: Thomas Müller-Pering, Autor: Andreas Michel u.a., Label: Raumklang, Leipzig 2001

Antonio Stradivari 1679 "Sabionari" guitar, Interpret: Krishnasol Jiménez Moreno, Autor: Martin Kirnbauer, Label: bmn, Basel 2015

La Guitarra dels Lleons. The Lion Guitar, Guitarras de la colección del Museu de la Música de Barcelona production of el Museu de la Música de Barcelona, Interpreten: Xavier Diaz-Latorre, Pedro Estevan, Autoren: Xavier Diaz-Latorre, Oriol Rossinyol Panyella, José Carlos Cabello, Label: cantus, Barcelona 2014

Musik aus dem Musikinstrumenten-Museum Markneukirchen. Werke von J. Haydn, W. A. Mozart, J. G. Naumann, Ersteinspielung auf historischen Instrumenten, Interpreten: Volker Niehusmann, Karsten Linck, Label: attacca, Markneukirchen 1996

Plucked Instruments in the Edinburgh University Collection of Historic Musical Instruments. Interpreter: Rob MacKillop, Author: Rob MacKillop, Darryl Martin, Edinburgh 2003

3D-Computed Tomography in the Service of (Not) Playing Historical Instruments

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Introduction

Before playing a historical instrument, an assessment is needed about the conservational risks as well as about the state of "originality" the object presents. Amongst examination methods, 3D-computed tomography (3D-CT) is relatively new and costly, but still a promising technology to support this type of assessment. Although CT has routinely been used in clinical imaging of humans for several decades, the imaging of objects that show a complex internal structure, composed of sometimes dozens of different materials, remains a challenge. Currently, there is a lot of experience as well as trial and error involved before achieving the best image quality within a certain type of musical instruments, e.g. trumpets, violins or pianos. A new 3-year project called MUSICES will create a standard for 3D-CT of musical instruments, aiming at making the method more available and easier to handle.

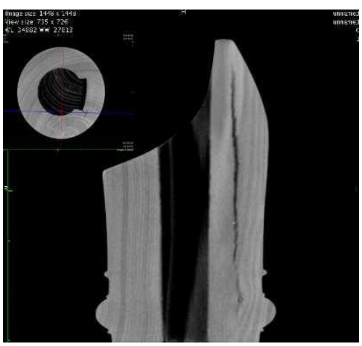

Figure 1: 3D-CT showing hidden crack in the top joint of a baroque recorder. Germanisches Nationalmuseum

Project co-proposers are Musikinstrumenten-Museum, Staatliches Institut für Musikforschung Preu-ßischer Kulturbesitz, Berlin; Staatliche Museen zu Berlin – Ethnologisches Museum; and Museum für Musikinstrumente der Universität Leipzig (all Germany).

International experts are sent by the collaboration partners University of Edinburgh (GB); Philharmonie II (ex-Cité de la musique, Paris F); and Musical Instrument Museum Brussels (B).

Methods

For the technical part, a representative corpus of approx. 120 musical instruments is compiled, coming mainly from Germanisches National-museum and being completed by objects from the co-proposers' collections. Main parameters are different materials, their combinations, and the size of the instruments. Experimental 3D-CT will issue recommendations for machine- and person-independent parameters. A best-practice paper will pro-pose workflows for preparing, handling and fixing musical instruments. For this, Fraunhofer EZRT provides industrial 3D-CT facilities from Nano-CT up to XXL-CT (pianos, cars etc.) with radiation energies from 10 to 9.000 kV.

The MUSICES standard will enhance Deutsche Forschungsgemeinschaft's (DFG) best-practice guide for digitization as well as the MIMO digitisation standard. MUSICES is funded by DFG and runs for 36 months from 1st of November 2014. Project partners are Germanisches Nationalmuseum in Nuremberg/Germany and Fraunhofer-Entwicklungs¬zentrum für Röntgentechnologie. (EZRT) in Fürth/Germany.

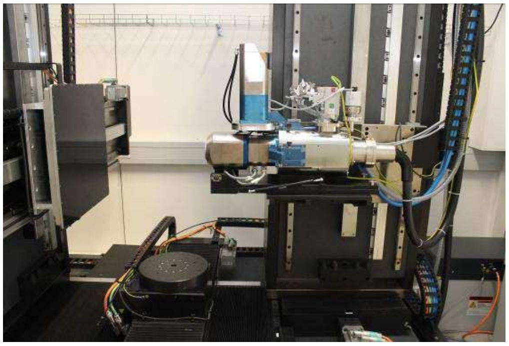

Figure 2: Tomosynthesis scanner. Fraunhofer EZRT.

For the standard part, the project group will seek advice and evaluation by international experts through organisations and projects such as ICOM-CIMCIM, AMIS, COST WoodMusICK etc. in order to cope with the needs of the musical instrument community.

A Study of the Modification of Oil-Based Varnishes by Different Ageing Processes

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Introduction

It is generally known that wooden musical instruments are covered by protective varnish layers made by different organic compounds. Historically, these varnishes had the aim of protecting the instrument from external agents and conferring an aesthetic value to the object. The organic compounds were generally natural products and could be extremely heterogeneous, such as drying oils, essential oils, tree resins and gums, insect resins, dyes, various proteins or polysaccharides used alone or mixed together, possibly purified, pre-treated or diluted in a volatile solvent [Echard, 2008].

It is known that the playing routine of the musical instrument can induce different changes on the varnishes due to the contact with the player, with a strong degradation of the organic layers and a consequent widespread wear of the varnish. The main interaction is due to the acidity of the player's skin, as well as the increase of temperature, humidity and mechanical abrasion.

In order to study the different properties of the organic compounds, a natural varnish used on violins of the XVII century was recreated following an ancient recipe, with linseed oil and colophony mixtures with different ratios. The specimens were aged by using UR%, T, pH variation cycles and mechanical processes of surface abrasion.

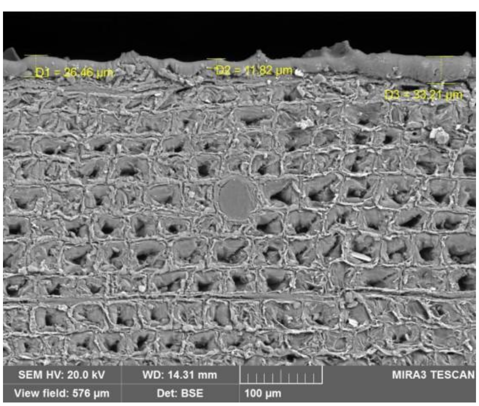

Figure 1: A cross-section SEM image of a wood specimen treated with a varnish layer.

Methods

Different layers of varnishes (oil and colophony 50/50) were applied on glass and wood specimens and were analysed before and after aging with exposure to an acid atmosphere and a solar lamp, and with different cycles of temperature and UR%. The specimens were investigated by FTIR spectroscopy analysis through a Nicolet iN10 Thermo Fischer micro FT-IR spectroscope, in ATR mode with germanium crystal; the spectral range was 4000–700 cm−1 and spectral resolution 4 cm−1, measurements were carried out with a minimum of 32 scans. Observations of the cross-section specimens embedded in acrylic resin were carried out with an Olympus BX51TF polarized light microscope equipped with an Olympus TH4-200 lamp (visible light) and an Olympus U-RFL-T (UV radiation). Various cross-sections and powder specimens were also studied with a FE-SEM Tescan Mira 3XMU-series scanning electron microscope equipped with an EDAX spectrometer at an accelerating voltage of 15–20 kV in high vacuum.

Results

Several hypotheses about the reactions in the varnishes before and after aging processes were performed, on the basis of the literature data [Azémard, 2014], and of the results of spectroscopic and morphological investigations. A strong degradation of the varnishes was observed after acid exposition, with a strong loss of cohesion of the varnish and an evident chromatic variation of the surfaces. In addition, different signals ascribable to the development of new compounds were detected by the FTIR technique. On the contrary, the aging cycles by variation of temperature and UR% seem to produce a lower worn-out of the varnish layers.

Discussion

The results obtained in this experimental study seem to agree with literature data and, in particular, highlight that the contact of an oil varnish with the acidity of the player skin represents the first cause of the degradation of the varnishes, with an increase of the craquelure process and a consequent detachment of the film and loss of material. Moreover, a significant increase of the degradation process was performed by the simultaneous effect of the mechanical abrasion and the high temperature and UR% on the violin surfaces, due to the continue contact with the player.

Acknowledgements

We would like to thank the Fondazione Antonio Stardivari Museo del Violino of Cremona for their collaboration and availability which has improved this research.

Bibliography

Echard et al, *Journal of Cultural Heritage*, 9:420-429, 2008.

Azémard et al, *Microchemical Journal*, 112: 137-149, 2014

The Role of Tonewood Selection and Aging in Instrument "Quality" as Viewed by Violin Makers

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Introduction

"Resonance woods" are the raw material used for the making of the violin family: Norway spruce (Picea abies) is used for top plates, and sycamore maple (Acer pseudoplatanus) is used for back plates [Bucur, 1992]. On the one hand, the mechanical/acoustical properties of these two preeminent woods for classical stringed musical instruments have been well studied. It is often recognized that high quality resonance spruce has low density, high modulus of elasticity, low damping and high anisotropy [Ono & Norimoto, 1983; Obataya et al. 2000]. When compared to "common quality" spruce wood, the resonance spruce shows atypical relationships between structural/visual features and mechanical/acoustical properties [Carlier et al, 2014]. On the other hand, physical acoustics and psychoacoustics studies were conducted on the behaviour of finished violins and the perception of their "quality" by players or listeners. However, while the link between the raw material and the finished instrument is made by luthiers, their practice and opinion has seldom been explored. According to the only psychosensory study on the subject [Buksnowitz, 2012], the selection of wood by violin makers would rather rely on visual criteria than on mechanical or acoustical properties that seem difficult to assess. It could also reveal the use of indirect indicators, and/or take into account personal or cultural preferences in wood choice [Brémaud 2012]. Empirical knowledge of luthiers is precious and can help us to appreciate the concept of "resonance wood". Therefore the objective of this ongoing study is to improve the understanding of the interactions between physic-mechanical properties of resonance wood, their natural variability, and the actual expertise of violin makers in the selection, qualification and processing of their raw material. Here we will focus on a survey conducted on the way instrument makers choose their wood, and their opinion about issues of time and aging.

Methods

To identify craftsmen's opinions, practices, empirical knowledge and their main questions, a "socio-technical" survey on both qualitative and quantitative grounds has been created. The survey was developed as face-to-face interviews using a modular and detailed questionnaire. It was designed in order to be applied to different instrument making specialities and to be used on other projects. As a first step the survey concerned the violin-family luthiers of Montpellier and then was extended to the rest of France. Suppliers were also questioned. In a second step an exploratory study was extended to Iranian makers of traditional string instruments. Quantitative analysis of the questionnaire was first conducted (using Sphinx software) while qualitative analysis of interviews' recordings (managed under Sonal software) is still in progress, which include opinions about the effect of playing.

Results

Makers reckon they rely mainly on empirical processes (but also historical) for their practices. They consider resonance wood choice to be one of the most determining factors in sound quality of the instrument. "Resonance wood's choice" and "Design" appear to be determining factors in both "Sound quality" and "Global quality" of the instrument (figure 1). "Lutherie's work" or "Varnish" are considered more relevant to "Global" than to "Acoustical" quality, while "Pre-stresses" and "Adjustment" are more related to "Acoustical" notions.

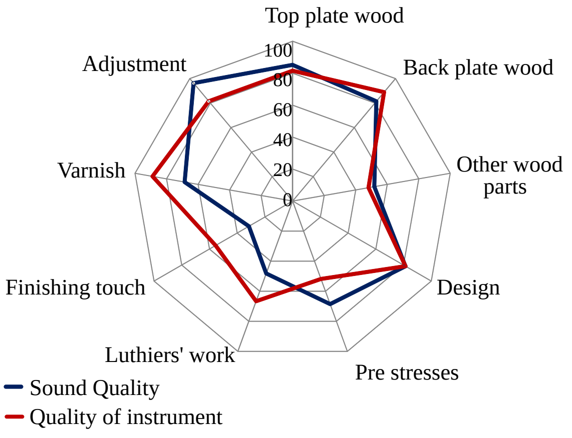

Figure 1: Importance scale of different fabrication parameters in "Sound quality" and in "Global quality of instrument"

Empirical qualification criteria taken into account by violin makers to choose spruce wood are mostly based, by order of importance, on cutting, density, percentage of latewood, growth ring uniformity and width. For maple, ring width seems to be the most important criteria for luthiers. Density, cutting plan and drying are also very important in the choice of maple. Unlike for spruce, colour appears more crucial for maple.

Most of the makers do not take into account the drying time before buying their wood. However they recommend a drying time equal to or higher than at least two years, before starting the fabrication. More than half of luthiers do not specifically seek for aged wood, even if they believe that the properties of their raw material can be changed by aging. When asked the question of "evolution of acoustical properties through time", they consider that such an evolution would be different depending on the instruments being played or not. The opinion on the effect of aging on different parameters of the instrument's wood is more contrasted when considered over the centuries (aging is thought to have very positive effect, or no effect, depending on properties) than when considering short-term aging (Figure2). For aging over centuries, there is a consensus about a positive effect on visual criteria, while there is weaker agreement about acoustical effects, and physical/mechanical properties are not thought to be much changed. For short-term aging (years or few decades), luthiers think that it more consistently affects the different considered properties, although with smaller maximum importance. Acoustical properties (followed by physical/mechanical ones) are though to "improve" more over years/decades than over centuries.

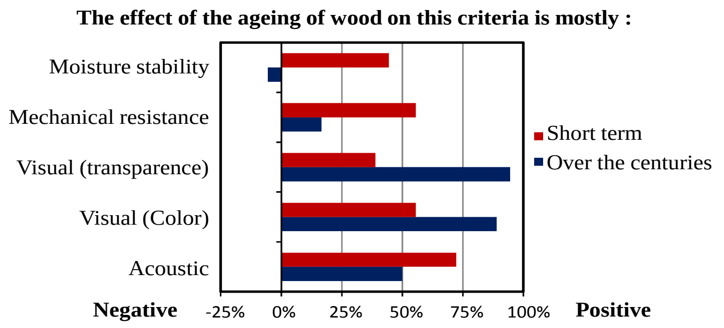

Figure 2: Importance scale of the effect (positive or negative) of wood aging on different parameters

Luthiers report a lot of interest in scientific approaches to musical instruments, especially regarding resonance wood. They show different "profiles" of interests for research in various fields (historical, forest, material, acoustical or sensory aspects) and these different "profiles" might reveal some kind of "school of thinking". Most of them would be interested in the development of simple tools usable in a workshop if they permit a better knowledge of the wood.

The perceptual criteria used for wood qualification can be visual, physical-mechanical, auditory and will require a more detailed study to evaluate the respective contribution of these different fields of perception.

Acknowledgements

We are grateful to the support of CNRS (PhD grant for Capucine Carlier), of the Région Languedoc-Roussillon (Young Researcher Prize to Iris Brémaud), and to all the makers we met, for the time and help they granted us, and their participation in the survey.

Bibliography

Brémaud, "Acoustical properties of wood in string instruments soundboards and tuned idiophones: Biological and cultural diversity". *Journal of the Acoustical Society of America*. 131(1): 807-818, 2012

V. Bucur, "Les bois de lutherie ». *Journal de physique* IV, 2: 59–65, 1992

C. Buksnowitz, R. Evans, U. Müller, and al. "Indented rings (hazel growth) of Norway spruce reduce anisotropy of mechanical properties". *Wood Sciences and Technology*, 46(6) : 1239-1246, 2012

C. Carlier, I. Brémaud, J.Gril, "Violin making "tonewood": comparing makers' empirical expertise with wood structural/visual and acoustical properties". *ISMA*, 325–330, 2014

E. Obataya, T. Ono, M. Norimoto. "Vibrational properties of wood along the grain". *Journal of Materials Science*, 35(12): 2993–3001, 2000

T. Ono, M. Norimoto, "Study on Young's Modulus and Internal Friction of Wood in Relation to the Evaluation of Wood for Musical Instruments". *Japanese Journal of Applied Physics*, 22(4): 611–614, 1983

Automatic Detection of Worn Areas of Stradivari Violin Back Plates

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Introduction

In recent years, multispectral imaging techniques, such as UV fluorescence, have become an essential step of the preliminary analytical procedure on artworks, especially in the field of ancient musical instruments. In fact, this imaging analysis technique can represent important knowledge about the distribution, retouching and wear of varnished areas. However, although this preliminary and non-invasive technique is essential in order to project a correct analytical campaign, there are a lot of limits in the interpretation of the results, with variables due to the equipment, capture and processing of images, as well as the interpretation of the distribution of the varnished areas [Comelli, 2008].

It is clear that there is a need to establish an analytical protocol in order to provide a correct method for selecting different areas and discriminating between several materials present on the surfaces of musical instruments. The aim of this work is to develop a new software system in order to automatically select the different fluorescence areas by chromatic selection, and to directly characterize the different organic materials of the violin surfaces.

Methods

For the acquisition of the images we prepared a dedicated photographic set, following the protocol adopted by British Museum for the UV induced fluorescence photography [Dyer, 2013]. In particular we used a Nikon D4 camera, two wood lamps for providing the UV illumination, and a Kodak 2e gelatine filter, in substitution of the Schott KV418, currently dismissed. UV fluorescence colours change in function of the materials and/or the paints present on the surface. The analysis of the acquired data shows that the areas where the wood and the wood filler are more evident and the paint coats are low or totally absent always have the same colour hue, with a different level of saturation directly proportional to the level of consumption. Starting from this consideration, small areas that are certainly worn have been manually labelled by an expert violin maker and then used as a training set for our system. This step was important to set the tolerance range for the chosen hue and the various saturation levels that correspond to different levels of wear. After the learning phase the system is able to automatically find all the regions of interest, also in areas which are not directly evident looking at the original photos, due to perception illusion (e.g. in back where the consumption is very low and hidden by nearest paint coats).

The algorithm uses HSV (Hue, Saturation, Value) a colour space closer to human perception than RGB. In particular, in this case, only the first two channels have been considered, since Value (i.e. the brightness) has no relevant variations in areas with no painting. During the computation, the fraction of the worn areas respective to the entire surface of the back is also automatically computed analysing the distribution of the resulting histogram. The background of the photo is excluded by the analysis applying an edge detection filtering algorithm. A set of parameter configurations for the system are available depending on the characteristics of the photographic set, such as the position and number of the lamps, quality of the camera, and so on.

Results

We tested the system on the historical collection of Stradivari violins preserved in the "Museo del Violino" in Cremona (Italy). The detected areas are highlighted with three different levels of wear: high in red, medium in orange, low in yellow.

Figure 1: Example of the application on the back of Antonio Stradivari Cremonese (1715). From left to right: visible, UV fluorescence, final result.

The program allows the user to visualize all of them or a subset, in order to focus only on the areas of major interest. Figure 1 and 2 show the results obtained on the back of the violin "Cremonese" (1715): it can be seen that the more consumed areas are mainly concentrated in the bottom and only partially on the top left side. Low worn zones are more diffused on the surface, with the exception of the middle-top area, which looks intact.

Figure 2: A zoomed detail of the top area of figure 1.

The percentage of detected worn areas on the total of the back is around 29%, whereas 5% is the high, 7% the medium and 17% the low. This percentage is compatible with the judgement of expert people.

Discussion

The test on the historical collection proved that the proposed solution is effective to underline worn regions and robust to small alterations of environment setup between photos (e.g. changes of exposure or of the distance from the lamps).

The more critical regions (red and orange) have a high level of accuracy, with the only exception being the purfling which can be wrongly classified due to its dark colour that masks the fluorescence. We are currently testing some specific corrections based on mathematical morphology, to totally exclude that zone from the analysis.

False positives are more frequent in yellow areas because the region of transition between low consumed and painted zones could have overlapping ranges of hue/saturation. When such condition occurs it could be useful to use an ad hoc setting configuration for refining the selection.

However, wrongly classified regions occur where there are heavy alterations to the original structure of the instruments, so in any case they could suggest to the user the need of a more detailed analysis with different tools (i.e. XRF or FTIR) able to deal with this ambiguity.

Acknowledgements

We would like to thank the Fondazione Antonio Stradivari Museo del Violino of Cremona for their collaboration and availability, which has improved this research.

We are grateful to the Fondazione Cariplo for the financing of these research activities.

Bibliography

Comelli et al., *Review of Scientific Instruments*, 79: 2008.

Dyer et al., *Multispectral Imaging in Reflectance and Photo-induced Luminescence modes: A User Manual*, The British Museum, Charisma Project, 2013.

Evolution in the Manufacture of the Basset Horn D'amour

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Introduction

In 2006, a project of instrument making was proposed by the Musée de la Musique in Paris, in order to make a facsimile of a basset-horn d'amour. The original instrument underwent several repairs and modifications between its manufacture, estimated at the last third of the 18th century, and 1840, so that its initial condition is not known. Examining these modifications, comparing this instrument with more recent basset-horns, and studying its acoustics allowed us to make assumptions about the evolution of the basset-horn.

The basset-horn d'amour

The basset-horn originates from South Germany in the 1760's. Initially its shape was curved, but then became angled [Rice, 1986]. The basset-horn "d'amour" is a single reed instrument and its bore is cylindrical. It plays one third below the A clarinet. In particular, this instrument was used in several of Mozart's pieces from 1784 to 1791 [Deutsch, 1956] and more recently in Dvořák's and Strauss's works.

The instrument owned by the Musée de la Musique in Paris (ref. E.2200), cf. Fig.1, was made in Germany or Austria in the last third of the 18th century by an unknown maker. It is made of curly maple. Initially it featured eight keys made of brass, but two more were added later on. The mouthpiece is connected to a straight barrel and a straight upper joint, operated by the left hand. This part is separated from the lower joint by a bend of 114 degrees. The lower joint is composed of a small joint, operated by the right hand, and a large joint. Two right angled lower bends connect the small joint to a cylindrical bell. Its bore is a 70.5 mm diameter sphere, open on the lateral wall of the bell. The end of the bell is closed by a cap. The qualifier "d'amour" in the instrument name is due to the shape of the bell. The instrument, pitched in F, plays over a range of four octaves and is tuned in A450.

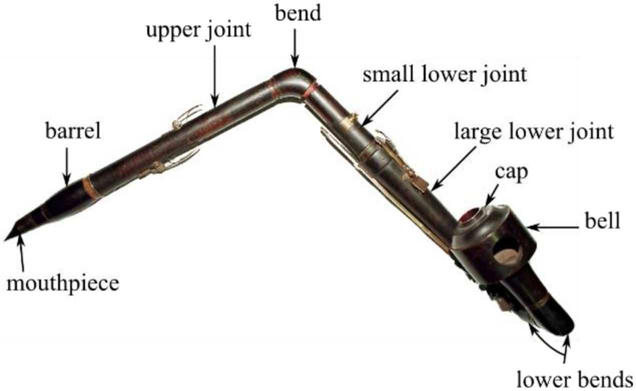

Figure 1: Basset horn "d'amour" (last third of the 18th century), curly maple, ten keys, and anonymous maker. It is kept in the Musée de la Musique in Paris, France (ref. E. 2200).

Evolution in the manufacture of the basset-horn

In Vienna, the basset horn experienced a fast evolution in the 1780's and 1790's, due to collaborations between Anton Stadler, clarinet player in the court, and maker Theodor Lotz [Poulin, 1982]. About 1791, Viennese maker Friedrich Hammig Junior elaborated a straight basset horn with eleven keys, one specimen of which is kept in the Vleeshuis museum in Antwerp, Belgium, cf. Fig.2.

Figure 2: Basset horn "d'amour", circa 1800, manufactured by Hammig in Vienna, with an extension downwards (including C3 and B2 or Bb2). It is made of boxwood and ivory. Its bell is similar to the bell of the basset horn E.2200 in the Musée de la Musique, Paris. It is kept in the Vleeshuis museum in Antwerp, Belgium (ref. AV.67.1.57)

Comparing the dimensions of the two instruments and examining the modifications of the basset horn E.2200 of the Musée de la Musique in Paris shows the evolution of basset-horn manufacture at the end of the 18th century. The acoustic impedance of the basset horn E.2200 and its facsimile were measured using a method developed by Le Roux et al [2008], and compared. Their comparison shows the influence of some manufacture modifications on the instrument's sound as listed below. First the bend between the upper and lower joint was shortened and then removed at the end of the 18th century, as well as the second bend of the lower part. Then the shape of the barrel became curved to improve the comfort of playing, as shown in Hammig's instrument, cf. Fig.2. From the end of the 1790's, the bore of the basset-horn became shorter and its diameter was extended in order to raise the instrument tuning. It reaches A450, in the case of the modified E.2200 basset horn. Its tone holes were also enlarged, which is typical from Viennese manufacture.

From the 1790's, an improved keywork made the basset horn more ergonomic. Hammig's instrument, cf. Fig.2, has three more keys than E.2200, allowing the player to play (written) C3 and B2 (or B♭2). Further, the D key in Hammig's instrument is closed while it was open in previous instruments, so that (written) C3 can be played by pressing only one key. The wooden cap of Hammig's instrument fits the outside of the bell's tenon joint, while it fits the inside of the tenon joint in the E.2200 basset horn. This solution reduces the risk of cracks and leaks. Both instruments were particularly fragile around the bends of the lower part, probably because of water condensation in the bore. Directing the bell aperture towards the bottom of the instrument or using a harder material (e.g. ivory) would have strengthened the basset horn. As a conclusion, the fast evolution of the basset horn "d'amour" between 1780 and 1840 mostly consisted of removing one bend between the upper and lower joint, improving the keywork, and shortening the bore and increasing its diameter. These modifications led to a more ergonomic instrument and a higher pitch tuning. They also raise the question of the purpose served by the second bend of the lower part in the earliest version of the instrument.

Acknowledgements

We thank the Agence Nationale de la Recherche for its support as part of the program Investissement d'avenir, reference ANR-11-IDEX-0004-02.

Bibliography

Deutsch, O.E., *Mozart's Catalogue of his Works 1784-1791*, New York: H. Reichner, 17-27, 1956.

Le Roux, J.-C., Dalmont, J.-P. and Gazengel, B., A new impedance tube for large frequency band measurement of absorbing material, proceedings of *Acoustics'08*, 2008.

Poulin, P. L., The Basset Clarinet of Anton Stadler, in *College Music Symposium*, The College Music Society, 67-82, 1982.

Rice, A. R., The Clarinette d'Amour and Basset Horn, *The Galpin Society Journal*, 97-111, 1986.

Removal of Iron Oxidation Products using Chealtors: A Preliminary Application on a Wooden Guitar

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Introduction

Viewed through the perspective of wooden artefact conservation, musical instruments are considered "composites", since they consist of a combination of organic and inorganic materials, such as wood and metal elements often made of iron (screws, tuners, bridges, etc.). When musical instruments are found in wet or humid environments (relative humidity above 65%) or during handling and use, their iron components start to corrode. Corrosion products usually generate colour alterations of the wooden substrate they are in contact with. Additionally, corrosion products can promote further deterioration of substrates as they are capable of catalysing various oxidation reactions. The corrosion of metal fastenings, in combination with the deterioration of the surrounding materials, can result in materials' mechanical damage [Godfrey et al, 2002] and weakening, therefore threatening the structural integrity of objects [Baker, 1974]. Therefore, the removal of the iron corrosion products from the wooden substrate is often a necessary process when conserving wooden musical instruments.

The common methodology applied in conservation for removing iron corrosion products includes the use of chelators in aqueous solutions which are capable of bonding with insoluble iron ions in order to solubilise them and remove them from the stained substrate. There are many published studies on chelators used on substrates, such as paper, textile, stone, metal, paintings and waterlogged wood for the removal of iron corrosion products [Roger, 1981; Slavin, 1990; Burgess, 1991; Phenix & Burnstock, 1992; Chapman, 1997; Margariti, 2003; Rivers & Umney, 2003; Almkvist et al, 2005; Fors, 2008]. Conversely, studies for composite dry wooden objects are scarce, probably due to the fact that the majority of chelators are water soluble and commonly applied via immersion baths which are unsuitable for dry wood. Porous organic materials, such as wood, are hygroscopic and anisotropic, and therefore immersion could promote further diffusion of corrosion products into the wood cells and more importantly it can induce uneven dimensional changes, resulting in distortion, warping, splitting of wood, dislocation of an object's parts etc. According to international standards, no musical instrument should normally be wet-cleaned [Museum and Galleries Commission, 1995] as this will certainly result in loss of original material, jeopardising the instrument to be non-functional. Therefore, aqueous cleaning treatments with prolonged contact are not recommended for dry wooden musical instruments. Minimum contact time with water, as well as the blotting of excess water, is necessary [Rivers & Umney, 2003].

Finally, according to the ICOM-CIMCIM code of ethics [Odell & Karp, 1997] an effective conservation/restoration approach of musical instruments should adopt methods that won't have an effect on their playability.

Based on the above, this study was set to investigate an alternative methodology for minimizing the wetting of wood during chelators' application. It has comparatively studied common chelators applied via aqueous solution or via gel formulations, and investigated their effectiveness in removal of iron corrosion products. Based on the results obtained, the most effective chelator was applied on the stained areas of a wooden guitar as a pilot trial.

Materials and methods

Two chelators were tested on wooden mock-ups stained with iron corrosion products (fig.1): EDTA (ethylenediamine tetraacetic acid) and DTPA (diethylenetriamine pentaacetic acid), both 1.5% w/v in deionized water. The pH of the solution was adjusted with sodium hydroxide 1M, to 6.2 for EDTA and 6.8 for DTPA. The same chelators were also applied in combination with a reducing agent SDT (sodium dithionite) 5% w/v. The four solutions were applied by two methodologies: a) an aqueous solution through a moistened cotton swab, and b) a gel made by the addition of a thickening agent CMC (carboxymethylocellulose) 10% w/v. For evaluating the efficacy of the formulations applied, gloss and colour of the wooden mock-ups were measured before and after cleaning with a portable gloss meter Rhopoint (model Novo-Gloss Trio) and a portable colorimeter Lovibond (model SP60 - RT Series).

Figure 1: A wooden mock-up stained with iron corrosion products

Results and Discussion

Iron corrosion products appeared to be effectively removed from wood by both chelators applied (fig. 2). However, colorimetry showed that DTPA was more effective than EDTA. Both EDTA & DTPA were more effective when applied in combination with SDT. However, residues of Na & S ions due to SDT use, could promote future deterioration of substrates. Further investigation is required for the selective removal of these chemical elements from the wood substrate. The application of the solutions with gel formulation was more effective than cotton swabs due to the gel's ability to maintain the cleaning solution potency and achieve complexation.

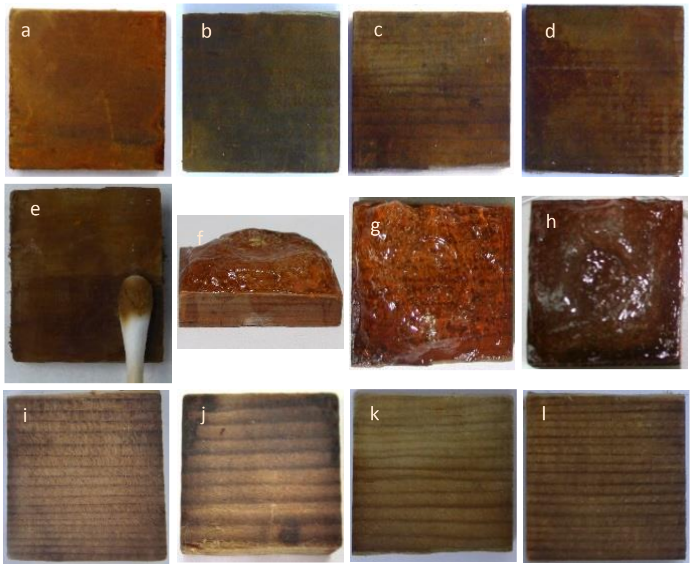

Figure 2: Procedure when applied on wooden mock-ups. a, b, c, d: before application of chelators; e, f, g, h: during application with cotton swab and gels and i, j, k, l: after cleaning (i: EDTA-SDT cotton swab, j: EDTA-SDT-CMC gel, k: DTPA-SDT-CMC gel, l: DTPA-CMC gel)

The more effective gel (DTPA+SDT) that was applied on the guitar on a pilot base (fig. 3) did not remove iron corrosion products on varnished areas, but appeared to be more effective within the stained unvarnished screw holes. However, the gel appeared to remove the entrapped dirt. No alterations (colour, gloss, cohesion) were observed on the varnish after macroscopic and microscopic examination, confirmed by gloss and colorimetry measurements.

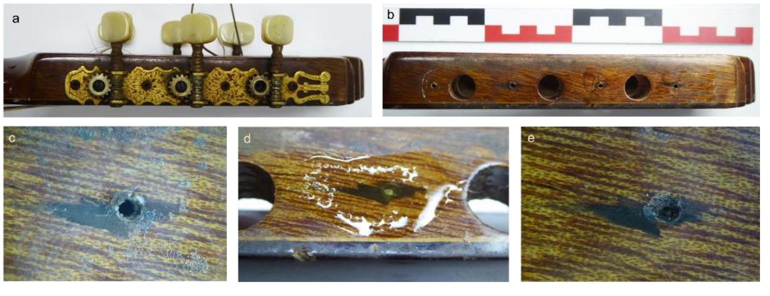

Figure 3: Procedure when applied on the wooden guitar. a. Before dismantling the tuning keys from the head. b. The surface below the metal parts with the stained screw holes. c. Microscopic image of the stained screw hole. d. Application of the DTPA with SDT gel. e. Microscopic image after the application of the chelators' gel.

Conclusion

The most effective chelator applied on the uncoated wooden parts of the guitar was DTPA in CMC with SDT; however, this approach wasn't effective on guitar varnished areas. It is assumed that the varnish layer did not allow the penetration of the solution of gel and the chelating process. Gels could however penetrate in damaged coating layers or when cohesion between the varnish layer and wood is weak. For these cases additional attention should be drawn as the removal of gels could be difficult. Moreover, it seems that chelators' gels do not have a negative impact on the varnish via macroscopic and microscopic observation; however, chemical analysis is needed in order to confirm this result. Finally, it is apparent that a more holistic evaluation is required when a conservation material and / or methodology is applied to a musical instrument. Several parameters should be taken into account beside the aesthetic appearance, such as the physical integrity of the material and the acoustic properties. More data is required in order to draw conclusions about the suitability of this methodology.

Further research

This research is ongoing and is also experimenting with natural chelators for the removal of iron corrosion products from wooden substrates, such as Deferoxamine (DFO), known as a "siderophore". This chemical is synthesized and excreted by the bacterium Streptomyces pilosus under conditions of iron deficiency [Raymond et al. 1984; Neilands 1995; Crisponi and Remelli 2008; Mossialos and Amoutzias 2009; Sandy and Butler 2009]. DFO is a hexadentate ligand that demonstrates high affinity in bonding with ferric iron and forms very stable complexes.

Bibliography

Almkvist et al, *Proceedings of the 9th ICOM -CC Group on Wet Organic Archaeological Materials Conference*, Copenhagen, 7-11 June, 2004, 202-210, 2005.

Baker A.J. Forest service research paper, 1974. Burgess H. *The paper conservator*, 15:36-44, 1991.

Burgess H. 1991. The use of chelating agents in conservation treatments. *The paper conservator*, 15, 36-44

Chapman V. *Painted Textiles*, UKIC Textile Section Forum, 1997.

Crisponi, G. and Remelli, M. 2008. 'Iron chelating agents for the treatment of iron overload', *Coordination Chemistry Reviews* 252(10–11): 1225–1240.

Fors, *Sulfur-Related Conservation Concerns for Marine Archaeological Wood: The Origin, Speciation and Distribution of Accumulated Sulfur with Some Remedies for the VASA*. Ph.D Thesis, 2008.

Godfrey et al, *Proceedings of the 8th ICOM-CC Wet Organic Archaeological Materials Conference*, Stockholm, 11-15 June 2001, 439-468, 2002.

Margariti, *Dust, Sweat and Tears: Recent Advances in Cleaning Techniques*, UKIC Textile Section, Spring Forum, London, 7 April 2003, 28-38, 2003.

Museum and Galleries Commission, *Standards in the Museum Care of Musical Instruments*, 1995.

Mossialos, D. and Amoutzias, G.D. 2009. 'Role of siderophores in cystic fibrosis pathogenesis: Foes or friends?', *International journal of Medical Microbiology* (299): 87–98.

Neilands, J.B. 1995. 'Siderophores: structure and function of microbial iron transport compounds', *Journal of Biological Chemistry* 270: 26723–26726.

Odell & Karp, *The Care of Historic Musical Instruments*, Edinburgh, 1997.

Phenix & Burnstock, *The Conservator*, 16:28-38, 1992.

Rivers & Ummey, *Conservation of furniture*, 2003.

Roger, Tappi, 64(3):43-44, 1981.

Raymond, K.N., Miiller, G. & Matzanke, B. F.1984. Complexation of iron by siderophores. A review of their solution and structural chemistry and biological function. [online] Available at: http://www.isolab.uni-luebeck.de/paper/Top_Curr_Chem_1984_123_49-102.pdf [accessed 12 December 2011]

Sandy M. & Butler A. 2009. Microbial Iron Acquisition: Marine and Terrestrial Siderophores. *Chemical Reviews*. 109 (10), 4580–4595

Slavin, *Dirt and Pictures Separated*, UKIC and Tate Gallery Conference, 49-50, 1990.

The Art and Science of the Rediscovery of a Nineteenth-Century Recorder

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Introduction

The decline of the recorder after its baroque golden age has been thoroughly analyzed by musicologists and organologists. Far less studied is its persistency in later musical culture. Recorder collections contain a relevant number of instruments dated from the last decades of the 18th century and well into the 19th century, documenting this persistency and its adaptation to new musical needs [Macmillan, 2008]. In some cases, the late popularity of the recorder has been a regional circumstance, like in the case of the Viennese Csakan or some instruments for popular or military music in the Americas. Some other late recorders are unique and extravagant pieces which can be regarded as experiments or unsuccessful adaptations. However, we also find in the collections a fair number of 'traditional' late recorders, some of which are of very fine craftsmanship. These document a minor but diffuse use, which was eventually also professional. One of these is the remarkable Noblet alto recorder of the Bate Collection of Musical Instruments in Oxford (collection #328).

Figure 1: The original instrument

This paper describes the process of making a modern copy of the instrument. The original instrument is not in good playing condition and mounts a low quality block (a consumable and interchangeable part in recorders). What, then, should a 'copy' of this instrument be? We describe a complex process including measurements, evaluation and tentative 'reverse engineering' of wood deformation, and some artistic choices which had to be made in order to obtain a musically meaningful result.

Methods

The original instrument was manually measured to an accuracy of about 0.05mm. Deformation of round parts was assumed elliptic and measurements refer to the principal axes. A digital CAD model of the instrument was made, reducing elliptic sections to round average sections. The resulting model displayed apparent deformations which were analyzed and compared to modern construction standards (see discussion). In particular, a marked decrease in the bore diameter was observed in regions of the bore where the wood was cut perpendicular to the grain direction, and at the same time likely exposed to high humidity fluctuations. A refined 'reverse deformed' model was made, and used as the basis for the construction of a first set of copies. Fabrication of the block required some artistic decision, since a copy of the ancient block would surely have led to a poor performance of the instrument. The difficult decision was taken to build the block according to today's knowledge, adapting it to the instrument body in order to produce the best sound and playability, as evaluated by renowned professional musicians. Fingering patterns of the original instrument were determined by the same musicians, taking into account historical practice and playability, and the copies were tuned accordingly.

Results

The first set of copies, comprising three instruments, is shown in Fig.2. The instruments are naturally tuned at A= 430Hz, very close to the original pitch. They are playable in the usual recorder range, two octaves and a third (F'-A'''), producing a very distinctive clear timbre, relatively different form the typical baroque recorder sound. The instruments have a quick and flexible response which makes them apt to playing technically complex music. They have been used in public concerts to perform duets and trios by W.A. Mozart and F. Devienne.

Figure 2: The first set of three copies.

Discussion

The process of copying an ancient instrument described above raises a number of questions both from the scientific and artistic points of view. The purpose of the copy was not only to preserve an object belonging to cultural heritage, but also to revive a "lost" cultural element, i.e. the sound of the instrument. This required the reconstruction of a fully functional instrument. Most features of the instrument were faithfully reproduced by the physical copy and by educated scientific guesses concerning the effect of ageing and usage on the wood. The latter could be further improved by the use of FEM simulations in future studies. In fact, it seems feasible today (though it is not immediately available) that a simulation methodology could predict permanent shrinkage on the basis of the humidity distribution in the instrument This would allow a more precise estimate of the shape of the pristine instrument. However, some details of the instrument, namely the so called "voicing" areas, had to be re-invented in order to build a functional instrument (and no simulation can overcome this lack of information). This was done according to the principle of "best fit" of the voicing to the instrument body.

The result is remarkable in several respects. Firstly, the fact that the reconstructed instrument presents the correct pitch and tuning confirms that the choices made during 'reverse engineering' of the instrument shape are correct. Concerning the sound, the copy exhibits a very distinctive sound, where the sound of the original is clearly recognizable. The marked difference with respect to the typical sound of early baroque recorders is particularly interesting. This sound bears some similarity with sound of the contemporary Viennese Csakan, but keeps the warmth and flexibility of baroque recorders, allowing it to play complex music requiring an agile instrument with a consistent voice in all registers. Summarizing, this copy experiment shows that an interdisciplinary work comprising modern craftsmanship, materials science and expert musicianship are necessary for reviving the sound of an ancient instrument.

Acknowledgements

The Bate Collection of Musical Instruments at the University of Oxford and its Curator David Lamb are gratefully acknowledged.

Bibliography

D. Macmillan, *The Recorder in the 19th Century*, Ruxbury publications, 2008 ISBN 978-1-904846-33-8

Levels and Angulations of the Left Hand: A Contribution to Violinistic Technique

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Introduction

All violinists and violists face a general difficulty as they play instruments of non-fixed intonation, which makes it very difficult to play in tune in a regular way. As the posture is completely nonsymmetrical, with no outside support for the handling and performance of the instrument, it is also quite easy to create wrong postures and wrong techniques. The library for violin technique is quite wide. We have early works from Leopold Mozart with his book *A Treatise on the Fundamental Principles of Violin Playing* (1756), and later works including that of great violinist Louis Spohr (1852) who wrote *Grand Violin School*. In modern days we have volumes by famous violinists such as Yehudi Menuhin, whose book *The Complete Violinist: Thoughts, Exercises, Reflections of an Itinerant Violinist* (1986) focuses on many subjects related to technique, study, and the daily life of a violinist. But material about biomechanics and ergo-anatomy of the left hand (referring to the interdigital movements and the relationship of the left hand to the arm of the violinists) is actually very limited. Many authors discuss different ways of working on intonation as exercises, or empiric opinions about possible problems. Examples of such works include books written by well-known pedagogues and masters such as Carl Flesh (1939), Leopold Auer (1921), Simon Fisher (1997), or D.C Dounis (1925). The only matter these authors address to the functioning of the left hand and the relationship between fingers is related to the left hand patterns mentioned in different ways by William Primrose (1960), Robert Gerle (1983) and Barbara Barber (2008). These outline the many interdigital patterns in a given hand position on the violin. However these approaches are not based on scientific and anatomical considerations. They do not provide an ergonomic and mechanical understanding to deal with different openings and distances, and progressive decreasing intervals between fingers in the many positions of the left hand in the violin scale.

We are proposing a conceptual understanding and functioning of the left hand, so that it is possible to answer in a reasonable and verifiable way the main three questions which are of importance to all violinists:

- How can we control the positional structure of the hand in order to obtain the same ratio interval distances in different strings, without muscle tension and in an organized manner?
- How can we control the opening of the fingers in great length intervals, without stretching and creating large palmar muscle tension which limits the performance?
- How can we structurally control the progressive reduction of the interval relationship between fingers on the violin scale, without recurrence to digital extensions that create much discomfort and palmar tension?

To answer these three main questions about the performance of the left hand in violinists, based on the main anatomic characteristics of the hand structure and functioning, we have suggested three possible answers which will be investigated in the laboratory. For the first question, we established the possibility of having four different basal levels for the action of the left hand in relation to the fingerboard, which allows the same function of the hand for the four strings. For the second questions, and based in the condyloid shape of the metacarpophalangeal joint, we suggested different levels of height in the same basal level, giving wider distances between fingers being able to play intervals of fifth, sixth minor and sixth major between first and fourth fingers without the need of stretching them. With regard to the third question we suggest the hypothesis of working with hand angulation in a given basal level in relation to the fingerboard, as a way of micro tuning the intervals between fingers in the different positions.

Methods

As a way of verifying these principles it is intended to develop a methodology in the Oporto University of Sport and the LABIOMEP – a laboratory of biomechanics within the university. The methodology is being developed and it includes: (i) electromyography analysis, using Delsys equipment to measure the muscle activity of the hypothenar and the Abductor digiti minimi muscle of hand of the fifth finger, the first interosseous and the Flexor digitorum profundus muscle of the fingers in the forearm; (ii) thermography analysis, using the camera FLIR SC7000 will be used to measure the arm and hand temperature during the exercises. The pressure measurement system, using Teskam equipment, will be put between strings and the fingerboard in the different techniques and positions. This system will measure the muscle resistance of fingers and the force they are able to put over the strings in the different positions. The motion capture system, using Qualysis equipment, is a technology that will capture, through the placement of small reflectors in the different joints, the motion of the hand and arm related to the violin fingerboard. This technology will give a digital motion of all the segments and joints of the hand, fingers, wrist, and arm when playing in real time all of the exercises proposed. All of this equipment will be used during the playing of some exercises (Figure 1) written for this methodology and based on the main hypotheses of the research. If verifying the hypotheses drawn previously, it is intended to create a preliminary model capable of explaining biomechanically the most comfortable, ergonomic and precise methods for the performance (and, consequently, for the learning) of the left hand in violinists and violists.

Figure 1: the score used in the research

Acknowledgements

My acknowledgements go to my co-orientator PhD Rui Garganta from the Sport University and to Dr. Pedro Fonseca from LABIOMEP, for their patience and great support in all this research project.

My gratitude also goes to my orientator PhD Professor Christopher Bochmann from Évora University for all his encouragement, and to José Xavier for the opportunity given to me and to this research.

Bibliography

Auer, Leopold. (1921) *Violin Playing-As I Teach It*. New York: Dover Publications

Bang, Maia (1919) *Maia Bang Violin Method, Part 1* by Barber, Barbara (2008) Fingerboard Geography for Violin. Van Nuys, CA: Alfred Publishing Company

Dounis. D.C.(1941) *Violin Player´s Daily Dozen. To keep the violinist technically fit for day´s work*. New York, HARMS

Fischer, Simon (1997) *Basics: 300 Exercises and Practice Routines for the violin*. New York: Edition Peters

Flesch, Carl (1939) *The Art of violin playing*. New York: Carl Fischer

Gerle, Robert (1983) *The Art of Practicing the violin*. London: Stainer & Bell

Menuhin.Y.(1986) *The Complete Violinist: Thoughts, Exercises, Reflections of an Itinerant Violinist*. New York.

Netter Frank (2000) *Atlas of human Anatomy*. Porto alegre: Artmed

Primrose, William (1960) *Technique is memory: a method for violin and viola players based on finger patterns*, London: Oxford University Press

Spohr's. Louis (1852) *Grand Violin School*. Boston: U.C.Hill

I.A.Kapandji (2007) *The Physiology of the Joints, Volume 1: The Upper Limb*; Churchill Livingstone

Characterization of Stiffness Tensor Components of Wood from Heterogeneous Plate Bending Tests

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Abstract

This work presents a study on the characterization of longitudinal-radial orthotropic elastic properties of Pinus pinaster Ait wood through a heterogeneous plate bending test. The proposed approach couples the deflectometry optical technique with the virtual fields method (Figure 1). Using this inverse identification method, all components of the bending stiffness matrix governing the Love-Kirchooff classical plate theory can be determined from a single test. The approach was firstly validated using a finite element model of the bending test, considering five different loading cases. Experimentally, a procedure was implemented in order to coat the surface of the solid wood plate to guarantee the specular reflection required in the deflectometry technique. The curvature fields required in the identification problem were numerically reconstructed from the slope fields by means of a polynomial approximation. The curvature fields, together with the applied punctual load and the plate dimensions, were then input in the virtual fields method for material parameter identification (Xavier et al 2007, Xavier et al 2009a; Xavier et al 2013). The values of the engineering constants obtained from the proposed approach were found in good agreement with regard to reference ones reported in the literature for the same species and determined from independent classic tensile and shear mechanical tests (Table 1) (Xavier et al 2004, Xavier et al 2009b).

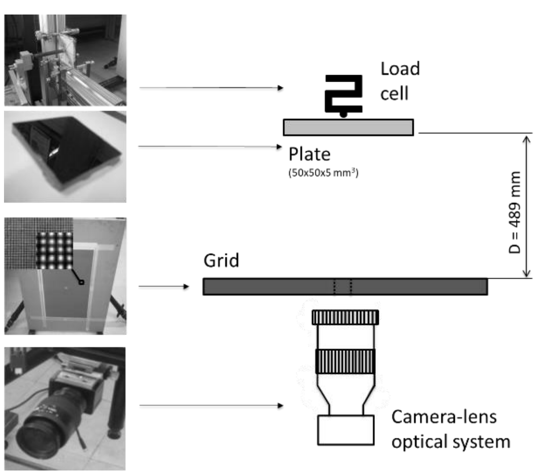

Figure 1: Schema of the plate bending test.

	E_L (GPa)	E_R (GPa)	LR	G_{LR} (GPa)
Reference	*15.13*	*1.91*	*0.47*	*1.12*
Mean	*12.55*	*1.396*	*0.639*	*1.190*
Std	*5.319*	*0.237*	*0.371*	*0.145*

Table 1: Engineering constants determined by the VFM.

Bibliography

Xavier, J.; Belini, U.; Pierron, F.; Morais, J.; Lousada, J.; Tomazello, M., *Wood Science and Technology* 47(2): 423-441, 2013.

Xavier, J.; Avril; S.; Pierron, F.; Morais, J., *Composites Part A: Applied Science and Manufacturing* 40(12): 1953-1960, 2009a.

Xavier, J.; Avril; S.; Pierron, F.; Morais, J., *Holzforschung* 61(5): 573-581, 2007.

Xavier, J.; Oliveira, M.; Morais, J.; Pinto, J., *Holzforschung* 63(2): 217–225, 2009b.

Xavier, J.C.; Garrido, N.M.; Oliveira, M.; Morais, J.L.; Camanho, P.P.; Pierron, F., *Composites Part A: Applied Science and Manufacturing* 35(7-8): 827-840, 2004.

Bringing the 'Davidoff' Stradivari Violin Back to Playing Condition: Measuring Changes

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Introduction

The 'Davidoff' (dated 1708, inv. E.1111) is the first of the five Stradivari violins to have entered, in 1887, the collection of the Musée de la musique, Paris. Its previous owner was Vladimir Alexandrovitch Davidoff (1816-1886), a general and private counsellor of the Emperor of Russia. This amateur violinist, stayed (and died) in Paris in the 1880s: He is known to have visited the Conservatoire and the Musée, and he subsequently bequeathed the instrument to the institution, which received it in 1887.

The instrument is well-preserved in general: in particular, the one-piece slab-cut maple back and the headstock still reflect today the excellent craftsmanship of the Stradivari workshop during this period. The previous set-up of the instrument was from the second-half of the 20th century (i.e. none of these parts was original from Stradivari workshop). In order to have the instrument played by a violin soloist, several conservation treatments and set-up restoration works were carried out on the instrument at the Musée's Conservation Department in the autumn of 2014.

The objectives were: first, to optimize the musical functioning and playing condition for the playing techniques of 21st-century players; second, to improve the visual appearance of the violin, whilst simultaneously fulfilling the specific deontological constraints involved in the material conservation of an historical artefact belonging to a museum collection.

In this context, conservation treatments included the removal of a part of the important varnish retouches on the soundboard, and the cleaning and re-gluing of several cracks and purfling areas. The previous set-up was removed, properly preserved, and replaced. In particular the fingerboard, bridge, soundpost and tailpiece were changed (Fig. 1).

The aim of this research was to evaluate the potential of these methods to identify some effects of the restoration works, including changes in:

- the geometry of the wood soundbox,
- the vibrational behaviour, in particular of the soundboard,
- the visual appearance of the cultural heritage artefact.

Figure 1: The 'Davidoff' violin, after conservation treatment, on 2015/03/10.

Methods

Several methods were used to document the physical state (geometry, vibrational properties, colour, etc.) of the instrument at several important steps of the work.

3D Scanner: A FARO Edge ScanArm ES equipped with a contact-less laser head mounted on a 3-axes arm was used [Pinçon et al., 2014]. In the acquisition conditions used, the spatial resolution is of 35 µm and the acquisition rate of 45120 points per second (Fig. 2).

Figure 2: Contact-less laser 3D scan of the 'Davidoff' violin. The previous set-up (including fingerboard and soundpost) is removed.

Impact Nearfield Acoustical Holography (IPNAH): IPNAH is a non-invasive acoustical method based on the response of the vibrating source measured in terms of radiating acoustic field with an array of microphones (Fig. 3). The vibrational behaviour of the source is deducted, in terms of normal vibration velocity, using an inverse calculation method based on spatial Fourier transforms [Le Conte et al, 2012a,b, Le Moyne et al 2012].

Figure 3: Impact Nearfield Acoustical Holography of the 'Davidoff' violin.

Reflectance multispectral imaging (RMSI) was used to investigate the changes in the reflectance properties of the soundboard produced by the retouches. Using a full-field MS imaging lab-designed system, described in [Simon-Chane et al., 2015], we collected 15-band MS acquisitions in the 400-750 nm range before and after the restoration (Fig. 4). We retrieved reflectance spectra for each pixel of the field-of-view using a calibration process based on a neural network [Mansouri et al., 2005]. This enables us to evaluate the effect of the retouches on the soundboard in a calibrated colour space.

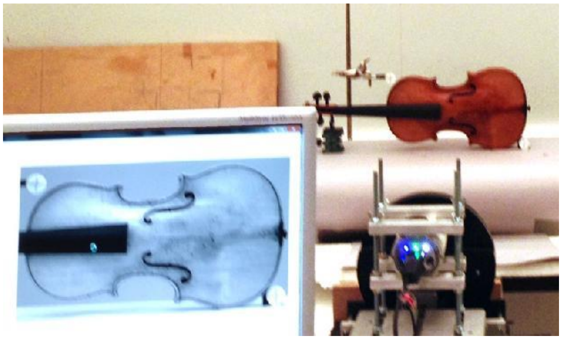

Figure 4: Reflectance MS acquisition of the 'Davidoff' violin. At the bottom right of the image is the camera seen from back and the 16-position automated filter-wheel (black cylinder).

Results

The several steps at which the acquisitions have been obtained will be described, before, during and after interventions, and first results will be presented. The correlation between the progress of the interventions and the metrological variations will be identified. First IPNAH measurements had been performed in 2012 on the 'Davidoff' in 2012 [Le Conte et al., 2012b]. Here, the modifications in terms of frequency and intensity of different vibration modes of the instrument will be shown, and discussed. The RMSI results will be discussed in terms of objective quantification and modifications of appearance.

Acknowledgements

The authors acknowledge Balthazar Soulier and Josselin Riehl (Atelier Cels, Paris) for carrying out conservation treatments and set-up of the instrument.

Bibliography

Le Conte et al, *Journal of Cultural Heritage*, 13:S161-S164, 2012a.

Le Conte et al, *'Acoustics2012' Proceedings*, 2012b.

Le Moyne et al, *Journal of the Acoustical Society of America*, 131:888-896, 2012.

Mansouri et al, *Physics in Signal and Image Processing PSIP*, 2005.

Pinçon et al, *MADAPCA 2011 Proceedings*, 85-92, 2014. Simon-Chane et al, Applied Spectroscopy, http://dx.doi.org/10.1366/14-07554, 2015.

Effects of Playing on the Practical Performance of Reeds Used for Woodwind Instruments

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Introduction

Woodwind instruments such as clarinet and oboe are equipped with vibrating plates called "reed" made by a kind of reed (Arundo donax). Many musicians claim that the quality of reed changes irreversibly with prolonged playing [Stein 1958; Obataya 1996a], but the mechanism of such irreversible change has not yet been clarified.

Since woodwind instruments are played by the exhaled air of players, the materials of those instruments are exposed to alternate wetting and drying. It should be noted that the reed contains a large amount of water soluble extractives, and that the extractives affect the vibrational properties of the reed [Obataya et al. 1999]. Therefore, the loss of extractives due to playing (i.e. wet-dry cycles) may affect the quality of the reed.

Another explanation for the irreversible change in reed property is the recovery of cell collapse. It has been reported that serious cell collapse is induced in the reed during drying, but the collapsed cells can be recovered by alternate moistening and drying [Obataya 1996b; Obataya et al. 2004]. Such a recovery may indirectly affect the performance of a reed.

In this study, the effects of wet-dry cycles and moist-dry cycles on the mechanical properties of reeds were investigated.

Materials and Methods

Arundo donax harvested for the production of clarinet reeds were used. Specimens of 70 mm (L) x 5 mm (T) x 0.5 mm (R) were prepared from the peripheral part and inner part of the internodes. For the wet-dry cycle and moist-dry cycle test, 9 and 15 specimens were selected, respectively.

The specimens for wet-dry cycles were dried on P_2O_5 under vacuum, and their absolute dry mass was measured. The specimens were then equilibrated at 25°C and 60% relative humidity (RH) for more than 3 days to determine their mass and vibrational properties. Next, the specimens were soaked in water under reduced pressure for 2 hours (wetting), followed by drying at 25°C and 60% RH. And then the vibrational properties of those specimens were determined. That wet-dry process was repeated 14 times. Finally, the specimens were soaked in water for 1 week to remove the water soluble extractives, and their absolute dry mass was determined.

The specimens for moist-dry cycles were moistened at 25°C and 100% RH in a desiccator under reduced pressure for 1 day (moistening). The specimens were then dried at 25°C and 60% RH for 1 day to determine their mass and vibrational properties. That moist-dry process was repeated 6 times.

Results and Discussion

Figure 1 shows the change in extractives content (EC) due to wet-dry cycles. The EC decreased by increasing number of wet-dry cycles. Due to these loss extractives, the mass of specimens decreased. The dynamic Young's modulus (E') and the loss tangent (tanδ) of specimens decreased by wet-dry cycles. These changes are plotted against EC in Figure 2. Changes in E' and tanδ showed a linear relationship with EC. That is, the loss of extractives is responsible for the changes in vibrational properties of reed during wet-dry cycles.

Changes in thickness of reed specimens are shown in Figure 3. The specimens became thicker by wet-dry cycles. Such a thickening was due to the recovery of cell collapse which had remained in the specimens. For musicians, the rigidity of reed (vibrating plate) is an important factor affecting their performance. Since the bending rigidity (E'I) of reed depends on its thickness as well as E', we need to consider the abnormal thickness swelling due to the recovery of cell collapse. Figure 4 shows the changes in the E'I and resonant frequency (fr) of the specimens during wet-dry cycles. In many cases, the E'I dropped in the early stage of wet-dry cycles, because of the loss of extractives accompanied with significant reduction in E'. In some specimens, the E'I was once reduced and then increased by wet-dry cycles. Such an increase in E'I was due the abnormal thickening resulting in the increase in the second moment of area I. On the other hand, the fr value is proportional to the square root of E'I/m, and the decrease in m due to the loss of extractives was large enough to cancel the drop in E'I. Consequently the fr always increased during wet-dry cycles as shown in Fig.4 (b).

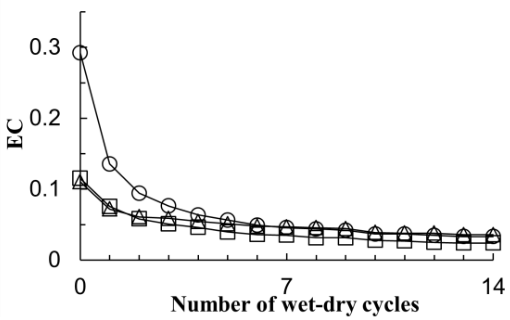

Figure 1. Change in extractives content (EC) of different reed specimens during wet-dry cycles. Circles, ρ = 390 kg/m3; Triangles, ρ = 483 kg/m3; Squares, ρ = 563 kg/m3

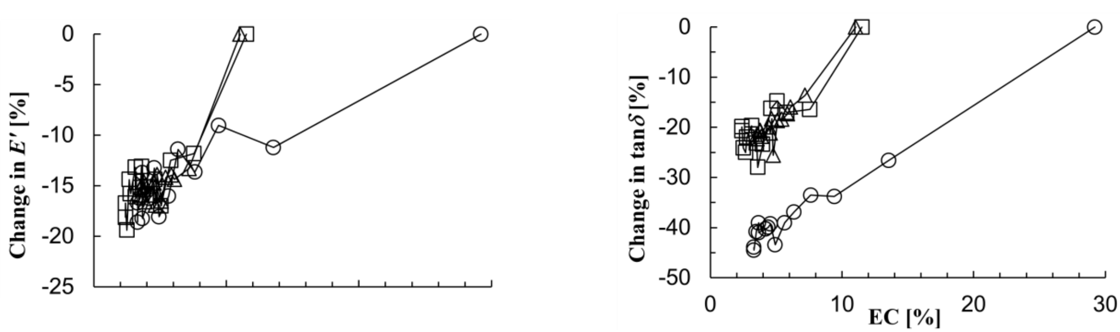

Figure 2. Change in (left) dynamic Young's modulus (E') and (right) loss tangent (tanδ) of Arundo donax specimens during wet-dry cycles plotted against extractives content (EC). See Fig.1 for legends.

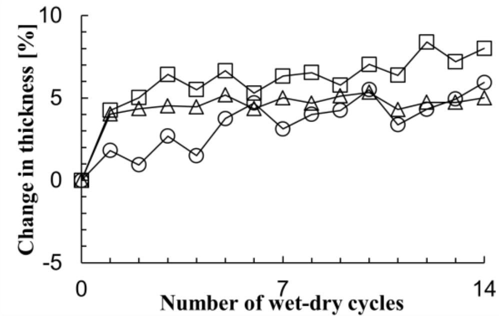

Figure 3. Change in thickness of Arundo donax specimens during wet-dry cycles. See Fig.1 for legends.

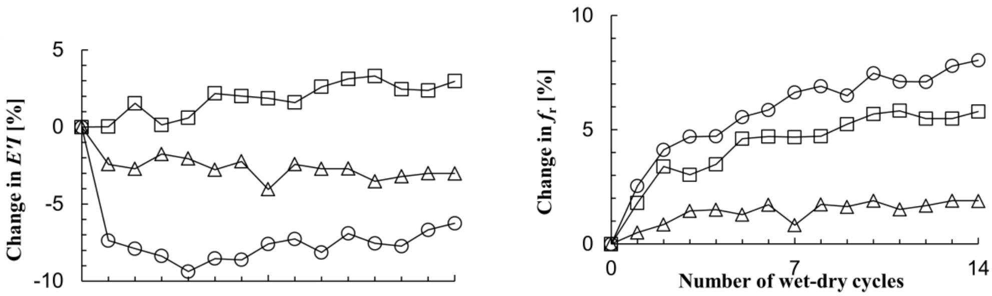

Figure 4. Changes in (left) bending rigidity (E'I) and (right) natural frequency (fr) of Arundo donax specimens during wet-dry cycles. See Fig.1 for legends.

The changes in vibrational properties and dimensions during moist-dry cycles were qualitatively similar to those of wet-dry cycles, whereas the former is slighter than the latter. All those results suggested that the practical performance of woodwind reed would change irreversibly during continuous usage. The recovery of cell collapse is a particular phenomenon in reed, but the loss of extractives can occur in the other woody materials. It should be noted that the extractives affect the mechanical properties of wood, and that these can be lost from the wood cell wall by moist-dry cycles, even in the absence of liquid water. Thus, the effects of moist-dry and wet-dry cycles are to be considered when the material contains water soluble and/or deliquescent extractives.

Acknowledgment

The authors are grateful to West Nippon Expressway Co. ltd. for their technical and financial support. We also thank to Mr.Kimura and Mr.Hiragi, reed harvesters, for their valuable advices.

BIbliography

Obataya E, *Pipers*, 181:32–34, 1996a

Obataya E, *Wood Res.Tech.Notes* 32: 30–65, 1996b

Obataya E et al, *Holzforschung*, 5: 63–67, 1999

Obataya E et al, *J.Wood Sci.*, 50: 295–300, 2004

Stein K, *Birch Tree Group*, New Jersey: 6–9, 1958

Influence of the Surface Condition in Wooden Resonators of Wind Instruments on the Acoustic Impedance

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Introduction

Wind instruments players typically play next to the bore resonances. The playability and the quality of wind instruments strongly depend on the frequencies, amplitudes and bandwidths of the bore resonances. The input impedance of wind instruments, which allows estimations of these characteristics, has been extensively studied [e.g. Backus, 1974; Wolfe et al., 2001]. The influence of the bore geometry on the impedance peaks is well known [Chaigne & Kergomard, 2008]. In addition, the inner surface of wooden resonators is typically polished and oiled by makers and players during the making procedure and the life of the instruments. These steps reduce the acoustic dissipation incurred by the air column [Boutin et al., 2017]. Recently, at the Musée de la Musique in Paris, the input impedances of a historical (not played) serpent made by Baudoin, and of an oiled facsimile of the same geometry in a playable state, have been measured. Their comparison revealed significant differences of Q-factors and amplitudes in the impedance peaks. This study demonstrates how oiling the inner surface of wooden pipes modifies the characteristics of their impedance peaks.

Materials and methods

A corpus of six pipes was provided by serpent maker Pierre Ribo. Three are made of maple, three of chequer tree. Each pipe is composed of two pieces, cut lengthwise, parallel to the trunk, and glued together. For each species, one pipe was immersed in oil; another was immersed twice, and dried for one week between baths, and one pipe was not immersed. The bores of the pipes are approximately cylindrical of diameter between 24.05 and 24.25 mm and length between 338.5 and 339.5 mm.

Many methods of acoustic impedance measurement have been previously developed and reviewed [Dalmont, 2001]. The one used in this study was developed by Le Roux et al. [2008]. For each measurement, one end of the pipe is placed in the plane of the open face of the impedance sensor, so that their axes coincide. The contact between the pipe and the sensor is sealed with silicone and petroleum jelly. The setup measures dimensionless impedances in this plane: $Z/(\rho_0 c_0/S)$, Z being the input impedance of the pipe, c0 and ρ0 the speed of sound and the density of air and S the area of the cross section. For each pipe, the impedance spectrum is measured between 20 Hz and 6 kHz, allowing estimations of the amplitudes, frequencies and Q-factors of the 12 lower resonances. The Q-factors are estimated by the quotient between the frequencies of the impedance peaks and their bandwidths at -3dB. The measurements are repeated and lead to estimation errors lower than 0.11% for the resonance frequencies, 1.9% for the Q-factors and 0.1 dB for the amplitudes.

Results

Among the pipes considered, the characteristics of impedance peaks undergo significant variations, as shown by the measurements of Fig.1.

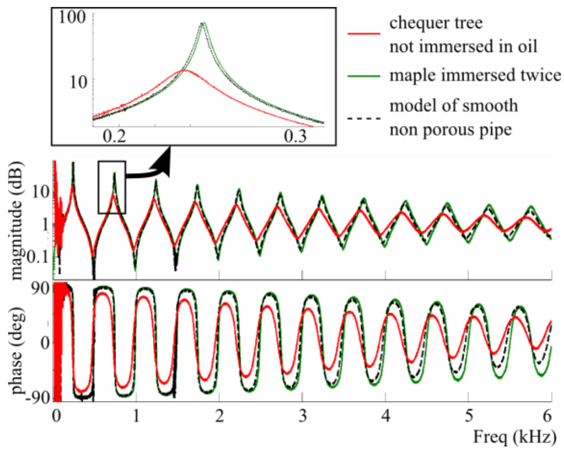

Figure 1: measured impedance of two pipes made of different wood species and with different surface conditions and impedance of a model of pipe with smooth and nonporous inner surface. For each pipe the bore has a diameter of 24.1 mm and a length of 339 mm

For the first 12 peaks, the relative standard deviations of these variations are 0.6% for the resonance frequencies, 32% for the amplitudes, and 32% for the Q-factors. These values are compared with a simple model of uniform cylindrical pipe, open at its far end, with length correction [Dalmont et al., 2001] and viscothermal losses [Fletcher & Rossing, 1991] – see black curve in Fig.1. When the diameter and the length of bore sweep the same ranges as those of the real pipes, the resonance characteristics of the model undergo much smaller variations than the measured ones: the standard deviations are 0.1% for the resonance frequencies, 0.2% for the amplitudes and 0.2% for the Q-factors. For the wood species considered, the measured amplitudes and Q-factors of the impedance peaks considerably increase when the pipe has been immersed in oil, as shown in Fig.2.

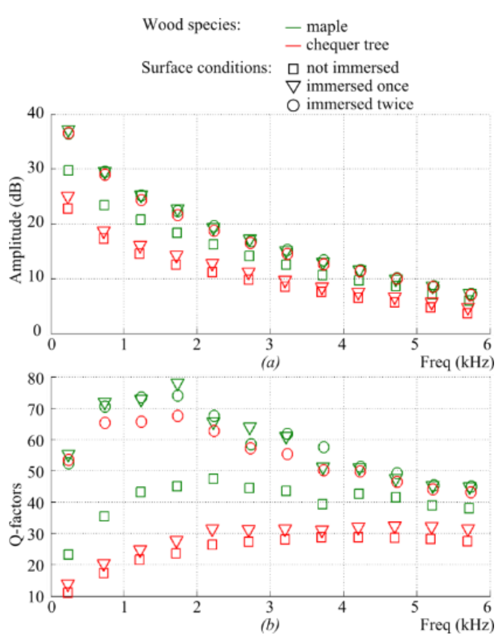

Figure 2: amplitudes (a) and Q-factors (b) of the impedance peaks of maple and chequer tree pipes having different surface conditions.

However the effect of a second immersion depends on the wood species: it is much larger on the resonance characteristics of the chequer tree pipes than on those of the maple pipes.

As a conclusion, immersing a wooden pipe in oil increases its resonance amplitudes and Q-factors significantly, and repeated immersions have a larger impact on chequer tree than maple.

This experimental study support recent results showing that polishing and oiling the bore tend to reduce the acoustic dissipation in wooden resonators of wind instruments [Boutin et al., 2017]. A model of acoustic propagation in pipes is being developed to quantify the impact of these steps on the acoustic losses incurred by the vibrating air column.

Acknowledgements

We thank the Agence Nationale de la Recherche for its support as part of the program Investissement d'avenir, of reference ANR-11-IDEX-0004-02, and Pierre Ribo, serpent maker, for providing the corpus of wooden pipes.

Bibliography

Backus, J., Input impedance curves for the reed woodwind instruments, *J. Acoust. Soc. Am.*, 56:1266–1279, 1974.

Boutin, H. and Le Conte, S. and Vaiedelich, S. and Fabre, B., and Le Carrou, J.-L., Acoustic dissipation in wooden pipes of different species used in wind instrument making: An experimental study, *J. Acoust. Soc. Am.,* 2840:2848, 2017

Chaigne, A. and Kergomard, J., *Acoustique des instruments de musique*, Belin Paris, chap.7, 2008.

Dalmont, J.-P., Acoustic impedance measurement, Part I: A review, *J. Sound Vib.*, 243:427-439, 2001.

Dalmont, J.-P. and Nederveen, C.J., and Joly, N., Radiation impedance of tubes with different flanges: Numerical and experimental investigations, *J. Sound Vib.*, 244:505-534, 2001.

Fletcher, N.H. and Rossing, T.D., *The Physics of Musical Instruments*, Springer-Verlag New York Inc., chap.8.2, 1991.

Le Roux, J.-C. and Dalmont, J.-P., and Gazengel, B., A new impedance tube for large frequency band measurement of absorbing material, *Proceedings of Acoustics'08*, 2008.

Wolfe, J. and Smith, J. and Tann, J., and Fletcher, N. H., Acoustic impedance spectra of classical and modern flutes. *J.Sound Vib.*, 243:127-144, 2001.

Effects of Continuous Vibration on the Dynamic Viscoelastic Properties of Wood

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Introduction

Many musicians believe that the quality of wooden musical instruments are improved by playing. Such a "playing effect" is recognized in stringed instruments such as violins, as well as woodwind instruments such as clarinets. Although no convincing explanation has so far been given for that empirical knowledge, it is considered that playing (i.e. continuous vibration) may affect the dynamic viscoelastic properties of wood. The first systematic study on the playing effect was conducted by Sobue and Okayasu [1992]. They have precisely measured the dynamic Young's modulus (E') and the loss tangent (tanδ) of 7 different wood species during continuous vibration. They have found that the tanδ was significantly reduced by the vibration irrespective of wood species and the amplitude of vibration, whereas the E' remained almost unchanged. Subsequently Hunt and Balsan [1996] have reported that forced vibration involved slight increase in E' and reduction in tanδ. All these results indicate that the acoustic properties of wooden instruments can change by continuous playing. Sobue and Okayasu have speculated that certain internal stress was induced by the drying of green wood, and the relaxation of such "drying stress" was responsible for the significant reduction in tanδ due to the vibration.

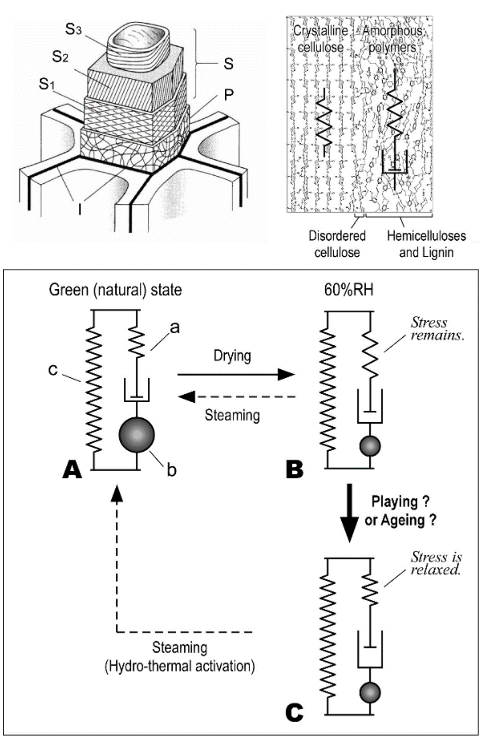

Fig.1. A viscoelastic model to explain the drying stress and its relaxation.

a, Viscoelastic part consisting of amorphous polymers; b, adsorbed water in the amorphous region; c, crystalline cellulose.

Figure 1 exhibits a simple viscoelastic model to explain the drying stress and its relaxation. When a green wood (A) is dried, hydrophilic amorphous polymers such as hemicelluloses and lignin are shrunk by the dehydration, whereas crystalline cellulose remains unchanged. Since the crystalline cellulose is much more rigid than the amorphous polymers, the shrinkage of amorphous polymers is restricted by the surrounding crystalline cellulose. Consequently, certain internal stress is induced in the wood cell wall (B). As the amorphous polymers are frozen in a dry state, the remaining stress and distorted conformation of the amorphous polymers remain unrecovered. The effects of drying on the viscoelastic properties of wood have been studied well. According to Furuta et al. [1998], green wood shows single glass-rubber transition at around 90°C, but additional transition appears at lower temperatures (50°C) when the wood is dried and rewetted once. That is, the distorted amorphous polymers are not relaxed unless they are hydro-thermally activated by boiling or steaming (heating in saturated water vapour), as shown in Fig.1 (B-→A).

If the relaxation of drying stress is responsible for the changes in viscoelastic properties of wood due to continuous playing, no playing effect is expected in green wood or hydro-thermally treated wood where no drying stress remains or the remaining stress is already relaxed. In many cases, however, the experiments have so far been conducted in dry condition, and therefore the effects of drying stress are still unclear. In order to discuss the influence of drying stress, we have tested the E′ and tanδ of spruce wood in saturated water vapour to prevent the samples from drying. Since green wood samples were not available, dry samples were steamed to relax the remaining drying stress, and the steamed wood samples were used instead of green wood.

Materials and Methods

Sitka spruce (Picea sitchesnsis) lumbers were cut into plates, 100 mm (L) × 10 mm (R) × 1 mm (T). One specimen was moistened at 100% relative humidity (RH) prior to steaming. The moistened samples were wrapped with moistened paper and enclosed in a plastic bag. The bag was then put in boiled water at 98°C for 3 minutes to steam the wood sample. Another dry specimen remained unmodified and conditioned at 25°C and 60%RH. E′ and tanδ of the wood specimens were determined by cantilever method. An end of the specimen was held by a brass clamp and the other end was tapped using a small glass ball. The deflection of the specimens was detected using a laser displacement sensor. The E′ and tanδ were calculated from the resonant frequency of the first mode and decrement curve, respectively. The dry specimen was continuously vibrated by a magnetic driver at resonant frequency for 48 hours while its E′ and tanδ were measured at 24, 48, 72, 96 hours after starting the continuous vibration. The testing condition was kept at 25°C and 60%RH. In the same manner described above, the E′ and tanδ of the steamed specimen were determined at 25°C and 100%RH. To keep the humidity around the sample, the equipment was installed in a closed box in which sufficient amount of water was placed in the bottom.

Results and Discussion

Dry specimen showed increase in E′ and decrease in tanδ during continuous vibration, and then these values remained unchanged. In contrast, the continuous vibration little affected the E′ of steamed specimen. This fact implies that the playing effect is related to the relaxation of drying stress. On the other hand, the steamed wood showed a decrease in tanδ during vibration, as the dry specimen did. A possible reason for the reduction in tanδ is the insufficient relaxation of drying stress due to short steaming time (3 min.). Otherwise, certain stress was additionally induced by the cooling after the steaming treatment, and such a thermal stress might be relaxed by the continuous vibration. Further detailed experiments are necessary to prove the contribution of drying stress.

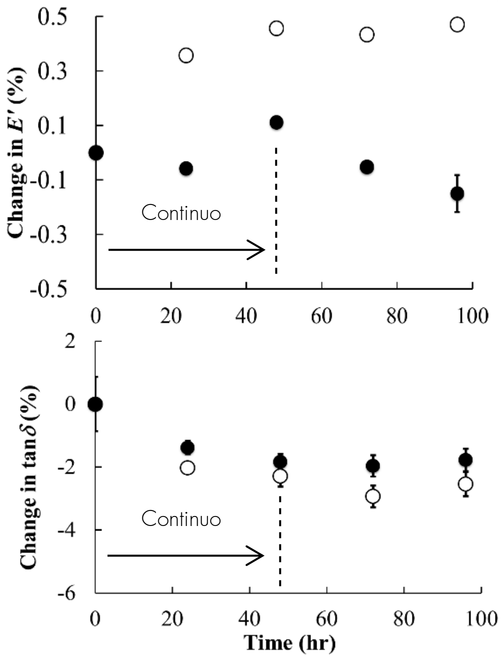

Fig.2. Change in E' and tanδ plotted against the elapse of time. O, Dry specimen tested at 60%RH; ●, steamed specimen tested at 100%RH.

Acknowledgements

We are grateful to Aoyama Harp Co. providing spruce lumber used in this study. We also thank Dr.Sandie LeConte for her technical support.

Bibliography

Furuta Y. et al, *Mokuzai Gakkaishi*, 44(2): 82–88, 1998.

Hunt D.G. and Balsan E. *Nature*, 379: 681, 1996.

Sobue N. and Okayasu S. *J.Soc.Mat.Sci.*, Japan, 41: 164–169, 1992.

Effect of Transitional Moisture Change on the Vibrational Properties of Violin-Making Wood

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Introduction

Wood is a very hygroscopic material. When submitted to different relative humidities (RH), which can typically be the case when an instrument is played in different places, the internal moisture content of wood will be changed. This is well known to result in dimensional swelling or shrinkage, and will also modify the wood's mechanical or acoustical properties. The equilibrium moisture content (EMC) dependence of vibrational properties (specific modulus of elasticity E'/γ which is related to resonance frequencies, and damping coefficient $\tan\delta$) has been well-studied for spruce wood along the grain [Obataya et al. 1998] and for various wood species in the three main directions of wood [Suzuki et al. 1980]. However, equilibrium state is only reached after a relatively long time (weeks), whereas the humidity changes encountered when an instrument is played in different places involve short time scales (hours) and are typically out-of-equilibrium. Previous research has shown the existence of transitional effects, notably on damping [Sasaki et al. 1988; Hunt and Gril 1996]. However these studies considered a single direction of anisotropy each, and wide steps of changes in relative humidity. The present work aims at observing transitional moisture effects on vibrational properties of violin-making woods (spruce and maple) over different steps and different histories of RH changes, in longitudinal and radial directions of wood.

Materials and methods

Material of Norway spruce (Picea abies [L.] Karst.) and of sycamore maple (Acer pseudoplatanus L.) was selected in order to reduce natural variability within the tested sampling. Longitudinal (12×2×150mm3, R×T×L) and radial (150×2×12 mm3, R×T×L) specimens were prepared with a fine planed surface. They were separated in 3 groups corresponding to 3 protocols of humidity changes:

- -Adsorption: samples were first oven-dried (48h at 60°C followed by 2h at 103°C), then stored in a desiccator for 2 weeks, then at 20°C and 35%RH, 50%RH, 65%RH, 85%RH, for at least 3 weeks each time. 8 radial and 8 longitudinal samples for each species served to measure properties at equilibrium, while 2 radial and 2 longitudinal for each species served to monitor transitional changes.
- -Desorption: samples were first immersed in water for 3 weeks, then stored (3 weeks or more until stable) at 85% RH, 65% RH, 50%RH and 35%RH. Same protocol/number of specimens as above.
- -Various humidity paths: 18 radial and 18 longitudinal specimens of each species were used to explore transitional changes with all possible steps between the above RH conditions.

Vibrational properties were measured by non-contact forced vibration of free-free bars using a device and software developed at LMGC [Brémaud 2006; Brémaud et al. 2012]. Specific dynamic modulus of elasticity E'/γ and damping coefficient $\tan\delta$ were measured at the first resonance frequency of bending. Repeatability tests indicated an experimental error of $\leq$2%, and a point of measurement could be taken every $\leq$1 minute.

Results and discussion

The equilibrium moisture content at different RH, as well as the hysteresis (that is, the difference between adsorption and desorption), was comparable between spruce and maple (Table 1).

EMC(%) at RH:	*35%RH*	*50%RH*	*65%RH*	*85%RH*
Spruce/adsorption	*5.5*	*7.9*	*10.4*	*17.4*
Maple/adsorption	*5.6*	*8.1*	*10.3*	*17.3*
Spruce/desorption	*7.1*	*10.1*	*13.1*	*20.5*
Maple/desorption	*6.9*	*10.1*	*13.3*	*21.1*

Table 1: Equilibrium moisture content (EMC, measured after ≥3weeks in stable conditions) of spruce and maple at different RH conditions.

Regarding moisture dependence of vibrational properties at equilibrium (Figure 1), the general trends were comparable to previous results [Obataya et al. 1998]. The differences between adsorption and desorption were small (once taken into account the hysteresis in EMC), with the exception of longitudinal damping in maple (maybe due to some extraction during water saturation). Damping in maple was slightly less affected by high moisture than in spruce. Mostly, properties in radial direction were clearly more modified by elevated moisture than in longitudinal direction, resulting in a strong increase in the degree of anisotropy.

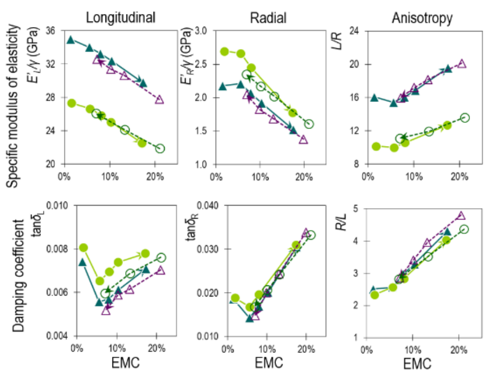

Figure 1: Dependence on Equilibrium moisture content EMC of specific modulus and damping and their longitudinal/radial anisotropy. (Triangles) spruce; (circles) maple; (filled symbols) adsorption; (open symbols) desorption.

When changing conditions of humidity, frequency and dimension evolved together with internal moisture content of wood. On the contrary, a transitional increase in damping was always observed, whether the humidity decreased or increased (Figure 2). The peak value of this increase in damping occurred from 30minutes to a few hours after changing conditions (depending on RH steps and direction of specimens). Then damping slowly decreased when evolving towards equilibrium state, which took 2-4 weeks; that is, after moisture content itself was stabilized. Moreover, this transitional increase in damping had a bigger amplitude when smaller steps in ambient RH were applied (Figure 3). For relatively small RH steps (e.g. 35-50% RH or 50-65% RH), transitional changes in damping clearly exceeded the differences between initial and final equilibrium values.

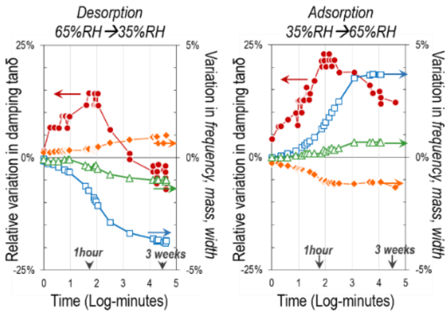

Figure 2: Example of transitional variations in (circles) damping, (diamonds) frequency, and (squares) mass and (triangles) radial dimension, along time after changing RH conditions. Longitudinal spruce specimens.

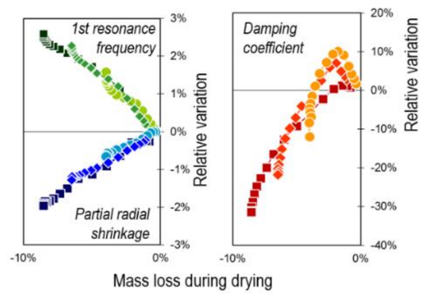

Figure 3: Relative variation through time in resonance frequency, shrinkage and damping plotted against mass loss during desorption from 85%RH to (circles) 65%RH; (diamonds) 50%RH; (squares) 35%RH. Longitudinal spruce specimens.

Conclusion

When wood is at equilibrium state, increases in relative humidity conditions reduce specific modulus of elasticity and increase damping, as is well known. Their anisotropy between longitudinal and radial direction is even more affected, which should modify vibration modes of instruments' plates. The transitional increase in damping occurring within a time scale of one/a few hours seems even more relevant to instrument playing conditions, all the more so that its amplitude is more pronounced over smaller differences in RH, typically in the range of 35-65% that could be encountered in normal concert places.

Acknowledgements

The first author initiated these experiments in the end of 2012 when a Post-Doc at EMPA, Switzerland, and continued the work at CNRS-LMGC from 2013. We thank Francis Schwartze and René Steiger for providing access to EMPA climatic rooms, and Patrick Langbour and Daniel Guibal for providing access to climatic equipment in CIRAD Montpellier.

Bibliography

Brémaud, I. (2006). *Diversity of woods used or usable in musical instruments making (in French)*, PhD in Mechanics, Université Montpellier 2, 302pp.

Brémaud, I., Y. El Kaïm, D. Guibal, K. Minato, B. Thibaut and J. Gril (2012). "Characterisation and categorisation of the diversity in viscoelastic vibrational properties between 98 wood types." *Annals of Forest Science* 69: 373–386.

Hunt, D. G. and J. Gril (1996). "Evidence of a physical ageing phenomenon in wood." *Journal of materials science letters* 15: 80-82.

Obataya, E., M. Norimoto and J. Gril (1998). "The effects of adsorbed water on dynamic mechanical properties of wood." *Polymer* 39(14): 3059-3064.

Sasaki, T., M. Norimoto, T. Yamada and R. M. Rowell (1988). "Effect of moisture on the acoustical properties of wood (in Japanese)." *Mokuzai Gakkaishi* 34(10): 794-803.

Suzuki, M. (1980). "Relationship between specific gravity and decrement of dynamic Young's modulus with water (in Japanese)." *Mokuzai Gakkaishi* 26(5): 299-304.

Hygro-Thermal Behaviour of an Historical Violin during Concerts

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Introduction

Hygro-thermo-mechanical behaviour of an historical wooden instrument is an essential requirement to understanding its behaviour, both under conservative conditions, and during playing when it is allowed/allowable. The use of an instrument without damage depends first on the state of conservation of its structure (it should be strong enough) and second on the hygro-thermal stresses during its use or displaying. Swelling and shrinkage produce significant stresses, especially in transversal direction, that could damage the object's integrity. To investigate the state of conservation as well as the playability of the Guarneri "del Gesù" violin (1743) known as the "Cannone", several experimentations were performed. A structural assessment and the computation of the deformative field under load were achieved in [Fioravanti et al. 2012]. The hygro-thermal conditions of conservation were assessed in [Goli et al. 2012] and the mechanical time-dependant behaviour in constant and variable relative humidity studied in [Fioravanti et al. 2013]. A hygro-thermal survey of the internal and external conditions of the violin during concerts was performed as well, and some results are presented in this paper.

Method

To assess the hygro-thermal impact of a concert on the violin, the effect of an exposition to a new environment and the effect of the musician, a series of nine concerts was monitored. The violin mass was measured immediately before and after each concert. The environmental conditions of the concert room were measured, as well as the microclimatic conditions inside the violin itself. The measure of the environmental conditions was performed with a conventional data-logger, while for the violin interior a special wireless chinrest was developed as in [Goli et al. 2011]. The specially designed and instrumented chinrest is shown in Figure 1.

Figure 1: The purpose-designed and sensor-equipped chinrest

Results

The average conservation conditions inside the display case were 52.5% of relative humidity (RH) and a temperature (T) of 22°C. Table 1 reports the average values of relative humidity and temperature inside and outside the violin during each monitored concert.

#	T ext (°C)	T int (°C)	RH ext (%)	RH int (%)
1	24.2	28.9	61.1	55.9
2	26.4	27.9	40.8	46.8
3	26.1	29.0	41.4	45.8
4	24.4	26.8	42.9	44.2
5	24.4	26.3	47.4	50.1
6	23.5	26.5	61.7	54.5
7	23.3	25.4	50.9	53.2
8	16.5	19.4	55.3	52.2
9	17.0	22.1	38.8	42.6

Table 1: Average violin internal and external temperature and relative humidity during nine concerts.

In terms of equilibrium moisture content (EMC), the average conservation condition is estimated at 9.65% of moisture content according to [Simpson 1998]. Table 2 reports the computed average values of EMC inside and outside the violin during each monitored concert as well as the mass variation between the start and the end of the concert. The time the instrument was kept out of the display case (TOC) is also reported as a direct indication of the time of exposure to a different thermos-hygrometeric condition.

#	EMC int (%)	EMC ext (%)	M (g)	TOC (hh:mm)
1	11.1	10.0	0.38	3:00
2	7.7	8.5	-0.65	2:45
3	7.8	8.4	-0.37	2:45
4	8.1	8.2	-0.39	2:00
5	8.7	9.1	-0.25	4:00
6	11.2	9.8	0.47	3:15
7	9.3	9.6	-0.15	4:15
8	10.2	9.6	0.08	4:00
9	7.6	8.1	-0.86	4:30

Table 2: Average VioTable 2: Average violin internal and external EMC, violin mass variation and Time Out of display Case (TOC) for the nine concerts.

Discussion

In order to verify the possibility of modelling the global hygro-thermal behaviour of the violin during concerts, the mass variation during the different concerts as a consequence of the following parameters were studied:

- RH as the difference between the average conservation RH and the violin internal averaged RH during a concert (1);
- RH as the difference between the average conservation RH and the environmental averaged RH during a concert (2);
- EMC as the difference between the average conservation EMC and the violin internal averaged EMC during a concert (3);
- EMC as the difference between the average conservation EMC and the environmental averaged RH during a concert (4).

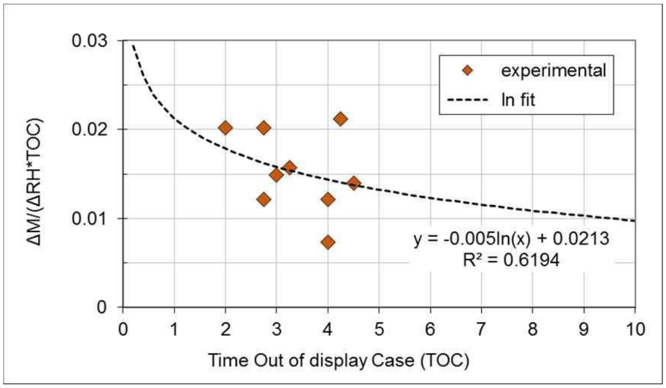

Figure 2: Mass variation in time referred to a variation of 1% between the RH inside the display case and the environment RH during concerts.

The phenomena was studied in terms of being able to result in a reasonable logarithmic fit. This kind of regression is the one expected to explain the phenomena (deriving from Fick's law diffusion of water vapour). Among the whole cases the best fit resulted between the conservation RH and the environmental RH during the concerts with a normalised root-mean-square deviation (CVRMSD) of 26.1% (case 2). The experimental data and the logarithmic fit are shown in Figure 2. Further information can be found in [Goli et al. 2017].

Conclusions

In the present work the mass variation of an historical violin measured at the display case opening and at the end of the concert was studied. The general principle is that the mass variation is widely dependent on the difference between the hygro-thermal conditions inside the display case and the conditions measured during the concert. During playing the environmental conditions of the room were monitored, as well as the conditions inside the violin. The fitting of the data with a logarithmic trend, being the one expected, has shown that among the various parameters considered (RH, EMC, inside and outside the violin) the difference between the average RH inside the display case and the average environmental RH is the parameter that better describes the mass variation. This research is a first step in the study of predictors of mass variation of a violin during a concert. Other steps need to be performed in order to associate with a given mass variation a potential risk for the instrument and thus guidelines for the conservation.

Acknowledgements

Authors would like to thank Dr. Laura Malfatto and Anna Rita Certo both working at Genoa Municipality for their cooperation and willingness to perform this research. All our gratitude to the violin players Feng Ning, Mario Trabucco, Peter Sheppard Skærved, and Salvatore Accardo for having allowed us to monitor their performances. Bogaro & Clemente had manufactured the dedicated chinrest. Mr. Danilo Dini was a valuable help in adapting the electronics and the sensors to the chinrest.

Bibliography

Fioravanti M, Goli G, Carlson B, Structural assessment and measurement of the elastic deformation of historical violins: The case study of the Guarneri "del Gesù" violin (1743) known as the "Cannone." *J Cult Herit* 13:145–153, 2012. doi: 10.1016/j.culher.2011.07.005.

Fioravanti M, Goli G, Carlson B, Viscoelastic and mechano-sorptive studies applied to the conservation of historical violins: A case study of the Guarneri "del Gesù" violin (1743) known as the "Cannone." *J Cult Herit* 14:297–303, 2013. doi: 10.1016/j.culher.2012.08.004.

Goli G, Fioravanti M, Busoni L, Giordano A, Wireless monitoring of the internal hygro-thermal variations in a historical violin during playing: device design and first results. In: Krüger M (ed) *Cult. Herit. Preserv.* EWCH P-2011 Proc. Eur. Work. Cult. Herit. Preserv. Berlin, Ger. Sept. 26 to 28, 2011. Fraunhofer IRB Verlag, pp 195–199, 2011.

Goli G, Fioravanti M, Busoni S, et al, Measurement and modelling of mass and dimensional variations of historic violins subjected to thermo-hygrometric variations: The case study of the Guarneri "del Gesù" violin (1743) known as the "Cannone." *J Cult Herit* 13:S154–S160, 2012. doi: 10.1016/j.culher.2012.04.007

Goli, G., Marcon, B., Busoni, L., Carlson, B., Giordano, A., Mazzanti, P., … Fioravanti, M., Antique violins: effect of the player on the moisture content. *International Journal of Conservation Science*, 8(2), 177–186; 2017.

Simpson WT, Equilibrium Moisture Content of Wood in Outdoor Locations in the United States and Worldwide. 11, 1998.

Hygro-Mechanical FE-Analysis of Wooden Objects: Importance of Reliable Prediction of Water Transport

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Introduction

In conservation of music instruments, climate conditions while storing or performing are of major importance, since a change in moisture content (MC) in wood could lead to cracking or other damages. While playing the instrument, fast humidity changes and large MC-gradients over the cross-section lead to high internal stresses. Furthermore, the material behaviour changes dramatically with changing MC, e.g. in hygro-expansion (swelling and shrinkage), strength and mechano-sorptive creeping [1-4]. Modelling of MC-dependent mechanical characteristics as well as the transport of moisture beneath the fibre saturation area (FSA) are necessary for a suitable numerical simulation of, e.g. stresses during a concert in terms of the finite element method (FEM). This abstract gives an insight into transport-modelling and its relevance in the scope of hygro-mechanical coupling and load-bearing analyses, i.e. its influence on stresses during humidity changes.

Methods

The transport of moisture below FSA is dominated by the three transport phases of water vapour emissivity, diffusion and sorption (see Fig. 1). Fick's law of diffusion is commonly used in its time-dependent formulation

$$\frac{\partial c}{\partial t} = \nabla \cdot (\underline{\boldsymbol{D}} \cdot \nabla \mathrm{c}) \qquad (1)$$

This assumption is suitable for steady-state moisture diffusion. The moisture flow is proportional to the gradient of the moisture concentration $\boldsymbol{c} = \boldsymbol{\rho_0} \cdot \boldsymbol{m}$, with the diffusion coefficient $\underline{\boldsymbol{D}}$, the density in absolute dry conditions $\boldsymbol{\rho_0}$ and MC $\boldsymbol{m}$. In transient simulations, this merely gives an approximation of the real transport behaviour. Discrepancies of the simulation compared to experimental tests are often named as "non-Fickian behaviour" (e.g. [5]). The larger the gradient of $\boldsymbol{c}$, the more pronounced are the deviations. Diffusion is homogenised to only one transport process. Beneath the FSA (normal conditions), moisture diffusion in the porous medium wood has to be divided into the two parallel processes of water vapour diffusion in wood pores with its concentration $\boldsymbol{c_v}$ and the bound water diffusion in cell walls corresponding to $\boldsymbol{c_b}$

$$\frac{\partial c_b}{\partial t} = \nabla \cdot \left(\underline{\boldsymbol{D}}_{\boldsymbol{b}} \cdot \nabla \mathrm{c}_b\right) + \dot{\mathrm{c}} \qquad (2a)$$

$$\frac{\partial c_v}{\partial t} = \nabla \cdot \left(\underline{\boldsymbol{D}}_{\boldsymbol{v}} \cdot \nabla \mathrm{c}_v\right) - \dot{\mathrm{c}} \qquad (2b)$$

Both processes interact via sorption term $\dot{\boldsymbol{c}}$. Theory and models for the anisotropic $\underline{\boldsymbol{D}}_{\boldsymbol{i}}$ and $\dot{\boldsymbol{c}}$ in phenomenological or multi-scale approaches are presented e.g. in [6-8].

Water uptake from the ambient air is considered by a surface emissivity model of water vapour. Three different models for the utilisation of clear and varnished wood are explained in [4].

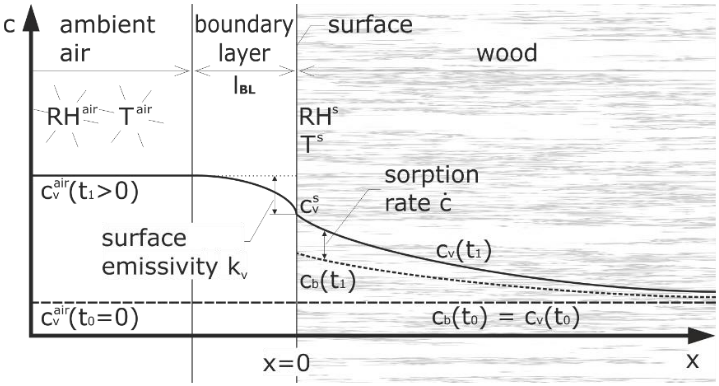

Figure 1: Distribution of water concentration during increasing RH.

In a transient hygro-mechanically coupled formulation, deformations $\boldsymbol{u}$ and water concentrations c_i are evaluated in one monolithic equation system

$$\begin{bmatrix} \boldsymbol{K}_{\boldsymbol{u},\boldsymbol{u}} & \boldsymbol{K}_{\boldsymbol{u},c_b} & 0 \\ 0 & K_{c_b,c_b} & K_{c_b,c_v} \\ 0 & K_{c_v,c_b} & K_{c_v,c_v} \end{bmatrix} \begin{bmatrix} \boldsymbol{u} \\ c_b \\ c_v \end{bmatrix} = \begin{bmatrix} \boldsymbol{F}^{apl} \\ 0 \\ 0 \end{bmatrix} - \begin{bmatrix} \boldsymbol{F}^{nr} \\ F_{c_b} \\ F_{c_v} \end{bmatrix} \tag{3}$$

with the components of the compliance matrix $K_{i,i}$ and the vectors of external minus internal loads on the right side. For a fully coupled model, the influence of the loading state on transport processes, primarily on moisture diffusion ("hygro-elastic effect" [9]), has to be considered additionally (e.g. [3]). In the case of large strains, the pore volume changes significantly, whereas for usually investigated small strains, the hygro-elastic effect may be neglected. Due to its mass ratio, the influence of vapour on mechanical properties is not considered.

Example and results

In the example, visualised in Fig. 2, a 1-phase and a 2-phase diffusion approach are compared concerning simulated stress-development by the MC-gradient during a relative humidity increase from $RH = 0.65$ to $RH = 0.95$. A modelled boundary layer to the ambient air (cf. Fig. 1), a 3-parameter sorption model [10] and diffusion models published in [11, 12] are applied. Due to the anisotropic swelling in r and t, strains are constrained leading to stress concentrations. The former approach leads to significant higher stresses, esp. in the critical directions r and t, whereas the latter shows as well peaks.

Discussion

Both transient approaches capture the stresses induced by constrained strains. In comparison, a steady-state analysis, where just the ultimate configuration would be regarded, leads to an underestimation of maximum stresses. On the other side, 1-phase diffusion leads to an overestimation and, thus, to unrealistic results as well. The results underline the importance of reliable transient moisture transport simulations in load-bearing FE-analyses considering changing climate.

A close-to-reality approach has to include the water vapour transport. Since a validation is missing here, it is referred to [7, 8] for the applied diffusion models.

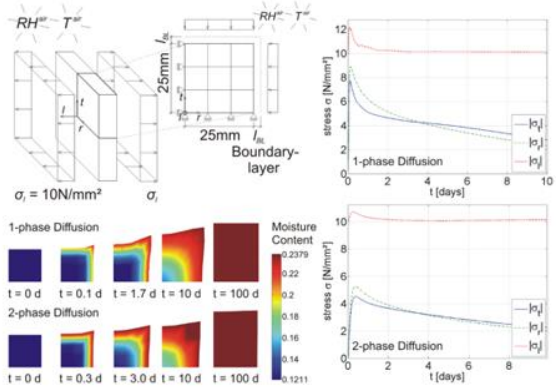

Figure 2: Comparison of different transient diffusion models on a hygro-mechanically loaded clear spruce wood sample for an increasing relative humidity from RH = 0.65 to RH = 0.95.

Acknowledgement

The authors gratefully acknowledge the support of the work by the German Research Foundation (DFG) within project KA 1163/25 "Modelling and Characterization of the Structural Behaviour of Wooden Cultural Heritage under Hygro-mechanical Loading".

Bibliography

[1] F. Kollmann. *Technologie des Holzes und der Holzwerkstoffe*. Springer, Berlin, 1982.

[2] T. Toratti. *Creep in timber beams in a variable environment*. PhD thesis, Helsinki University of Technology, 1992.

[3] P. Niemz. *Physik des Holzes und der Holzwerkstoffe*. DRW, Leinfelden-Echterdingen, 1993.

[4] S. Reichel. *Modellierung und Simulation hygro-mecha¬nisch beanspruchter Strukturen aus Holz im Kurz- und Langzeitbereich*. PhD thesis, Technische Universität Dresden, 2015.

[5] S. Avramidis and J. F. Siau. An investigation of the external and internal resistance to moisture diffusion in wood. *Wood Science and Technology*, 21:249–256, 1987.

[6] K. Krabbenhøft and L. Damkilde. A model for non-fickian moisture transfer in wood. *Materials and Structures*, 37:615–622, 2004.

[7] H. Frandsen. *Selected constitutive models for simulating the hygromechanical response of wood*. PhD thesis, Aalborg University, 2007.

[8] J. Eitelberger. *A multi-scale material description for wood below the fiber saturation point with particular emphasis on wood-water interactions*. PhD thesis, Technische Universität Wien, 2011.

[9] C. Skaar. *Wood-Water Relations*. Springer, Berlin, 1988.

[10] C. Zuritz et al. Desorption isotherms of rough rice from 10°C to 40°C, *Trans. ASAE*, 22:433–440, 1979.

[11] R. Schirmer. Die Diffusionszahl von Wasserdampf-Luft-Gemischen und die Verdampfungsgeschwindigkeit. *VDI*, 6:170–177, 1938.

[12] C. Skaar and J. F. Siau. Thermal Diffusion of Bound Water in Wood. *Wood Science and Technology*, 15:105–112, 1981.

Playing Historical Clarinets: Quantifying the Risk

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Context

It has been stated that the conservation and use of historic woodwind instruments is problematic because they are in very different states of preservation, and they are made from a wide variety of materials. Furthermore, their method of playing incurs rapid changes of temperature and relative humidity, the results of which can be catastrophic. This unpredictable behaviour makes clear guidelines for using early woodwinds impossible to establish (Barclay 1997). This level of uncertainty in the development of damages has led to the widespread assumption that woodwind instruments in public collections should not generally be played under any circumstance. On the other hand instruments in private collections have been extensively used by musicians without evident damages being noted, and many of the damages that are found on historical instruments are not apparently related to playing. The paper presents research in progress which, at this stage, has concentrated on clarinets. The research aims to quantify the risks and establish whether preventive conservation strategies and guidelines can mitigate those risks.

Survey of Damages and Measurement of Moisture Gradients

A survey of the damages that can be found in historic clarinets in UK museum collections has begun. The survey includes the study of catalogues, images and archives as well as technical examination of clarinets to document and classify damages. This is being augmented by empirical data collected from discussions with instrument makers, musicians, curators and conservators. The damages have been classified in an attempt to identify their potential cause. This has included split ferrules (metal and ivory), cracks in the wood associated with the key fastenings, and cracks in the different sections of the bore. Specifically, identifying cracks in the barrel and the bell which appear to relate to differential moisture or temperature gradients between the outside and the inside of the clarinet when played. A database has been setup to collate documentation, images and information gathered during the project (eventually to be online). Within the UK the following collections will be considered: Museum of Music (RCM), the Musical Instrument Museum (Edinburgh University), The Bate Collection and The Horniman. Other collections in Europe and the USA will be contacted and potentially involved in the project, particularly: Cite de la Musique (Paris), Germanisches Nationalmuseum (Nurenberg), Staatliches Institut für Musikforschung Preussischer Kulturbesitz (Berlin) and the Metropolitan Museum of Art (New York). The UK collections are being investigated first. ICOM-CIM CIM (International Committee for Museums and Collections of Musical Instruments) will be a platform from which to communicate and discover the relevant international collections as further research develops. The initial focus has been on the Sir Nicholas Shackleton collection at the University of Edinburgh, an extensive collection of 766 complete clarinets circa 1750-present (not including large clarinets and basset horns).

Definition of Damages

Damages were subdivided into: mechanical damages (cracks in the wood and cracks in the ferrules); warping and swelling; losses (chips, missing keys, pads, springs, ferrules and bell rim); missing sections (usually the mouthpiece, sometimes the barrel). From an initial detailed examination of 40 clarinets across the collection with a focus on the makers Simiot and Albert, the majority of damages were, as expected, in the barrel and the bell. The next most common damages were cracks around L0, L1, R0 and R1 hole positions.

Figure 1. 4935 Bb 5 J.F Simiot, Lyon, circa1810 Boxwood. Split initiating at L1. © C. Young

Clarinets When Played

Although there are many publications on the acoustics of clarinets, only one paper exists (to the authors' knowledge) which includes experimental work measuring breath moisture in woodwind (Stein 2004). Our research is focused on measuring the temperature and moisture gradient, and the rate of moisture uptake specifically imposed on clarinets when played: it takes into account different materials used in their construction, and different configurations of the parts for both wooden modern and period instruments. In particular, clarinets made from boxwood and/or mixed wood, as the moisture uptake is high and more differential expansion is expected. Preliminary testing was performed with a Noblet N 25 year old Grendilla wooden clarinet. This instrument has been regularly played and was used to gain an understanding of the rate of change in RH before subjecting historical instruments to moisture gradients. Figure 2 shows that a single blow in the lower register will lead to the RH at the bell end of the instrument going from 38%RH to 65%RH in seconds. This is also pitch dependent, suggesting that it relates to increased air flow and hole coverage. The bell of the clarinet is of particular interest because it is turned from one block of wood crossing over the growth rings which may account for the splits following the grain. There also appears to be a difference of opinion as to how much splits in the bell affect the quality of the sound. Values of 95%RH are measured inside the barrel after a single breath. The wetted reed inserted into the mouth piece results in an increase in RH of at least 20-30%RH.

Further data has been collected from clarinettist and Director of the RCM, Sir Colin Lawson. Temperature, RH and airflow were measured before and during playing of three pieces with three different clarinets used for performance. In all cases, while playing, the average temperature was 31 degrees C, average RH 95% and maximum air speed 0.43 m/s inside the barrel were recorded. The testing on "model" and historic clarinets has included accurate measurement of the relative humidity inside and outside the bore at different points. The sensor used for measuring the ambient relative humidity and temperature is s EL-USB -2-LCD+, while measurement of RH and temperature inside the bore utilises a low profile temperature and humidity iCelcius 20 probe which sits inside the clarinet without restricting airflow when played. Airflow measurements inside the bore were also made with a hotwire anemometer. Measurement of the change in internal bore diameter was made with a telescopic bore gauge and Micro-Mag internal measuring micrometer. Using published data on the moisture response of different woods, an attempt at correlating the experimental results with the specific behaviour of different clarinets will be made. This correlation will take into account the contribution of metal components and individual structure of the instrument; in order to reach a better understanding of long term dynamics of degradation and assessment of risk.

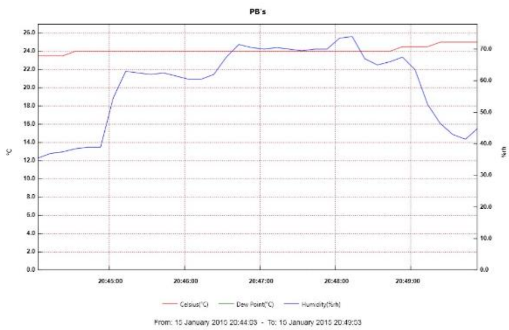

Figure 2. Noblet N Ambient-lower-higher-lower-ambient. Continuous playing with 10 second blows.

Non-invasive techniques and more accurate measurement methods are being investigated including Electronic Speckle Pattern Interferometry ESPI, CT scanning and other mechanical methods to measure deformations and strain distributions. The aim of the testing is to dynamically measure the deformation of the whole instrument when artificial breath moisture is introduced. There is a problem in scanning clarinets with the keys in position because they mask the X-rays over parts of the wood. Removing the keys leads to a change in the internal stresses that would be present in the real case. However, to understand the barrel and bell of the instrument, CT offers the best possibility of imaging changes in dimension associated with the wood structure. To calculate the internal stresses that initiate and propagate cracks we need to measure the deformation of the wood during moisture changes. Typically, the barrel has the most cracks, highest moisture, is easier to measure and model and importantly, alters tone. Therefore tests on a boxwood clarinet barrel (before final shaping) have been performed to assess whether the deformation can be measured by CT while one end is immersed in water (Figure 3).

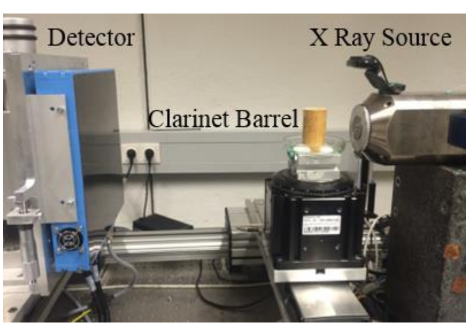

Figure 3. CT Scanning at Fraunhofer EZRT.

The measurements were very promising showing that, as would be expected, there is difference in the rate and degree of deformation between the inner and out diameter of the barrel; the inner diameter reducing faster as the wood swells. This leads to internal stresses which could cause cracking. The next stage of testing will be to introduce the "artificial" moisture breath within the barrel to confirm that the deformations which occur are measurable with CT scanning.

Impact

The results of this research on clarinets will eventually serve as the basis for a more extensive study of different typologies of woodwind instruments, and will set the methodological framework and research methods for the further developments in this direction. The long term aim will be an increased understanding of the behaviour of materials, and the creation of a benchmark system to guide curators and musicians in the assessment of the risks related to playing historical clarinets: the effect and best procedure of conditioning, practical ways to quantify risk and guide the decision making process.

Acknowledgements

- Jonathan Santa Maria Bouquet and Jenny Nex, Edinburgh University.
- Colin Lawson, Royal College of Music.
- Daniel Bangham, Cambridge Woodwind.
- Andy Lamb, Bate Collection, Oxford
- Fraunhofer EZRT, Germany

Bibliography

Barclay, L., 1997. *The Care of Historic Musical Instruments*, Edinburgh: Museums & Galleries Commission, 1997, p. 100). Myer A., 2007 ed. *Catalogue of the Nicholas Shackleton Collection*, pub. Edinburgh University Collection of Historical Musical Instruments.

Stein, I., 2004. *Die Blasfeuchte in Holzblasinstrumente* Teil 1: *Holzblasinstrumente*, Firnisse, 236 S. 116 Abb., 15 Tabellen. Kt

Humidity in Woodwind Instruments Due to Playing: Effects and Risks for the Wooden Structure

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This study was carried out in 2001 for a thesis at the Cologne Institute of Conservation Science (University of Applied Sciences Cologne) [Stein, 2004]. It was inspired by a question that sometimes appears in collections of musical instruments: Is it advisable to play ancient woodwind instruments which have not been used for a long time and which should be preserved for the future? Is it possible to minimize the risks that accompany the moisture input? The study analyses the effect of humidity on an instrument. Theoretical considerations based on the physics of the wooden structure as well as exemplary experiments help especially to answer the question of whether a time limit on playing can prevent damage to the instruments. According to the type of woodwind instrument, characteristic damages give evidence of moisture-induced processes.

Theoretical considerations of the effects of playing a woodwind instrument

The player generates air of 36°C and 100% RH which above all affects the mouthpiece and the part of the tube nearby. As preliminary tests showed, liquid water due to condensation is present immediately. Although the wooden tube warms up during playing, liquid water is constantly present in the inner bore. A simplified model of a tube suffices to describe the fundamental reactions to the moisture input: the wooden wall of the inner bore should absorb humidity and transport it to the dryer regions of the outer wall. (Wood absorbs liquid water more rapidly than water vapour.) Consequently a swelling process should begin which, because of the moisture-gradient in the wall, leads to strain and stress as schematically shown in Fig. 1.

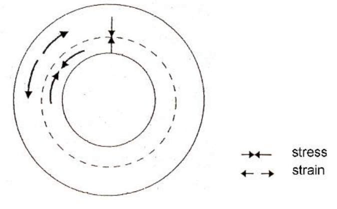

Fig. 1: Cross section of a wooden tube during the swelling process: Tangential stress in the inner wall as well as radial stress; tangential strain in the outer wall.

After a certain time of water absorption from the interior of the bore and diffusion through the wood, the tube will have reached the maximum degree of swelling. This results in an increase of the outer as well as the inner diameter. (Fig. 2)

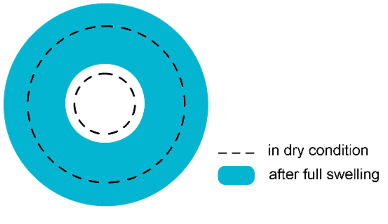

Fig. 2: Dimensional change after full absorption of humidity. The broken lines indicate the dimension before moistening.

After playing the instrument the drying process begins. Now basically a reaction opposite to the swelling should take place.

Experimental verification

These theoretical considerations were confirmed in a series of experiments. Samples of wooden tubes were moistened from the inside for a specific time (one up to 20 minutes). Afterwards the dimensional changes were measured over up to 47 hours. The inner diameter was measured with the FLUT-Woodwind Bore Gauge System, Version 1.00, the outer diameter with a calliper gauge.

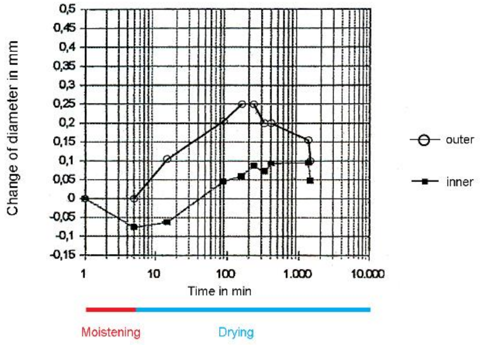

Fig. 3: Dimensional changes of the inner and outer diameter after moistening for 5 minutes.

The wooden tubes reacted differently according to the varied parameters (size, wood species, hydrophobicity, region of the tube – in the middle or at the front). Although the number of samples and experiments did not meet the number required for statistical evaluation, basically the following reactions were observed:

Mostly the moistening led to an instant narrowing of the inner bore. The outer diameter, on the other hand, could either remain constant or increase. (Fig.4).

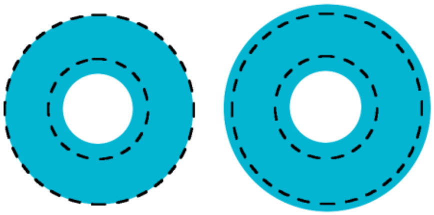

Fig. 4: Two possible reactions on moistening. The broken lines indicate the dimension before moistening.

After the narrowing, the inner diameter started to increase. A concurrent increase of the outer diameter was observed mostly on tubes with a thin wall. (Fig. 5)

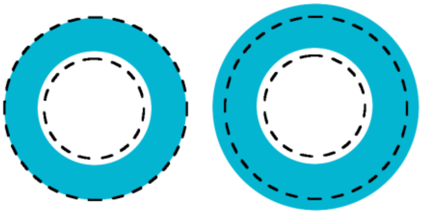

Fig. 5: Increase of inner diameter (left); increase of both inner and outer diameter (right).

After reaching a state of maximum swelling as shown in Fig. 2, the swelling decreased. During this process, again, on some samples a reduction of the wall thickness was observed. (Fig.6)

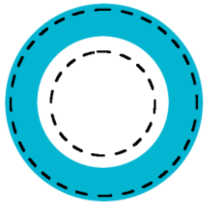

Fig. 6: Reduction of the wall thickness.

The amount of the dimensional changes was evaluated and compared to:

1. the recommended limits for climatic changes in public collections of art and cultural heritage,
2. the yield-point of wood.

The observed maximum dimensional changes of up to 5% swelling and up to 2% reduction of the wall thickness of the tube must lead to plastic deformation and includes an increased risk of crack initiation.

Conclusion

The swelling reaction of the wood is instant. It is impossible to give a time limit of playing that is free of the risk of damage. The amount of swelling and the induced tensions depend on different factors. Above all, the condition of the instrument (hydrophobicity, beginning micro-cracks, and continuity of use) is a central factor for risks. Methods of hydrophobicity that do not change the document character of the historical instrument should be further investigated.

Acknowledgments

- Prof. (ret.) Friedemann Hellwig, University of Applied Sciences Cologne, Germany
- Prof. Dr. Klaus Dreiner, Hochschule für nachhaltige Entwicklung (HNE), Eberswalde, Germany
- Klaus Martius and Markus Raquet (Dipl.-Rest.), Institut für Kunsttechnik und Konservierung (IKK), Germanisches Nationalmuseum, Nuremberg, Germany
- Fa. Moeck, Celle, Germany

Bibliography

Marion F. Mecklenburg, Charles Tumosa, David Erhardt, Structural Response of Painted Woodsurfaces to Changes in Ambient Relative Humidity, in: *Painted Wood: History and Conservation*, Proceedings, Williamsburg, The Getty Conservation Institute, 1994 (S. 499)

Stefan Michalski 1994, 'Relative Humidity and Temperature Guidelines: What´s Happening?' in: *CCI Newsletter*, Bd. 14, 1994, S. 6-8

Ilona Stein, Blasfeuchte in Holzblasinstrumenten. Vorgänge und Risiken für das Holz, in: *Studien zur Erhaltung von Musikinstrumenten*, Teil 1: *Holzblasinstrument, Firnisse*, (Hrsg. Friedemann Hellwig), Kölner Beiträge zur Restaurierung und Konservierung von Kunst- und Kulturgut, Band 16, München 2004, S. 9-121.

Numerical Simulation of Piano Soundboard Straining Induced by Humidity Changes

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Introduction

FEM (Finite Element Method) makes it possible to solve multiphysical problems with complicated geometry and the anisotropic behaviour of wood. With the help of parametric modelling it is very easy to reconfigure models (geometry, conditions, material), so it enables performing sensitivity and "what-if" analyses. Acoustic properties of piano were studied e.g. by Suzuki and Nakamura [1990], Boutillon [1988], Hall [1992], Chaigne and Askenfelt [1994] and others. Giordano [1997], Giordano et al. [2004] described the vibrational properties of a piano soundboard with the FEM model. Berthaut et al. [2003] used FEM for description of low-frequency dynamic behaviour of the piano soundboard with ribs. Hashimoto and Umetani [2000] built a coupled model of a soundboard with bridges and solved combined effect of these parts. Cuenca and Caussé [2007] published detailed numerical analysis of interaction between soundboard, bridges and strings. Ortiz-Berenguer et al. [2008] described the natural frequencies of a grand piano soundboard with use of ANSYS software. The effect of string pressure on the natural frequencies of crowned soundboard with ribs was examined by Mamou-Mani et al. [2008].

Methods

The numerical simulation of behaviour of the piano soundboard, ribs, bridges and wooden frame has been performed with use of the Finite Element Method (FEM) in an ANSYS software. An important step was to build a material model of spruce wood derived especially from the mass, natural frequency of samples and literature data. These models were verified in simplified cases (clear orthotropic specimens). The model of heat transfer in wood under constant conditions of humidity combined with the dimensional changes of wood was constructed in ANSYS. This FE model was constructed for the description of isothermal moisture diffusion in wood. An analogy of heat and moisture diffusion (also thermo-expansion and hygro-expansion) in the wood was used. Stress-strain relationship for linear-elastic material (Hooke's law) including internal (initial) stress and stresses induced by hygroexpansion is given by:

$$\{\sigma\}=[D](\{\varepsilon\}-\{\varepsilon w\}-\{\varepsilon O\}) \qquad (1),$$

where: [D] is elasticity matrix, $\{\varepsilon\}$ is elastic component of strain, $\{\varepsilon w\}$ is moisture component of strain and $\{\varepsilon O\}$ is initial strain. Generally, the moisture flow {r} is described by Fick's law:

$$\{r\}=-d\,\nabla w \qquad (2).$$

Diffusion of moisture w is assumed as anisotropic and diffusion coefficient d is a tensor. Moisture strains could be described by change of moisture content w and coefficient of thermal expansion or hygroexpansion a (swelling/shrinkage of wood):

$$\varepsilon w=\alpha .\, W \qquad (3).$$

From the 2nd thermodynamic law and Hooke's law with decomposition of strains (equation 1) the stress - strain - moisture coupling could be described by following this constitutive hygro-elastic equation:

$$\{\sigma\}=[D]\{\epsilon\}-[D]\{\alpha\}\Delta w \qquad (4).$$

Numerical models of the soundboard were designed for bare boards, ribbed boards and boards with bridges. These models correspond to stages in the manufacture of piano and describe impact of individual components on the behaviour of boards.

Figure 1: Finite-element model of piano soundboard.

Definition of a material model is based on literature data [Bucur 1995, Požgaj et al. 1997, Skaar 1988, Siau 1995]. In the case of mechanical-moisture analysis the material parameters are computed for constant temperature condition, then the dependence on moisture content is defined. Analogously, in the case of thermal-mechanical problems, the parameters are defined for constant moisture content and dependence on temperature is defined.

Definition of a material model is based on literature data [Bucur 1995, Požgaj et al. 1997, Skaar 1988, Siau 1995]. In the case of mechanical-moisture analysis the material parameters are computed for constant temperature condition, then the dependence on moisture content is defined. Analogously, in the case of thermal-mechanical problems, the parameters are defined for constant moisture content and dependence on temperature is defined.

Results and Discussion

FE analyses work with the change of parameters of material models by temperature or moisture content (MC). Soundboard will change its dimensions (or the stresses will be induced in the material) with the sorption/desorption of MC in relation to changes of environment (humidity, temperature).

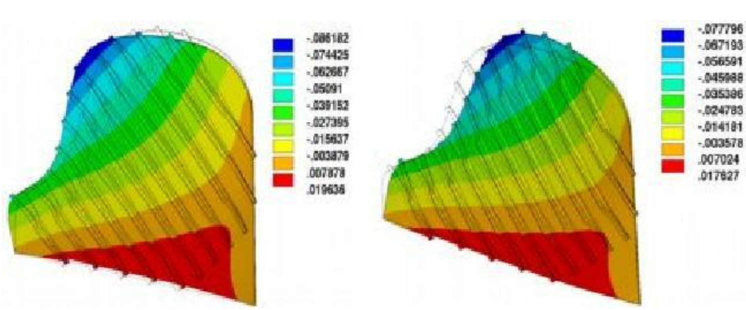

Figure 2: Dimensional changes of soundboard - nodal displacements [m] perpendicular to board - with increasing (left) or decreasing (right) of MC by 2%.

The MC influence dynamic behaviour of soundboard in two ways. Firstly, by changing the material parameters with the changing of MC, secondary by pre-stress generation. The moisture stresses in heterogeneous construction of soundboards with ribs are induced even by homogeneous MC distribution. Decreasing MC mainly induces tension stresses and most of the natural frequencies are increased. The influence of MC change is in a very wide range (theoretically from 0% to 20%) on the first fifty natural frequencies studied. The relationships are linear: with the increase of moisture content the natural frequencies decrease. The influence of MC is strong in the case of density and moduli of elasticity (especially longitudinal and radial normal modulus). For example, the influence of MC on first natural frequency is given by regression equation (coefficient R2 close to 1):

$$y = -0{,}307 \cdot x + 30{,}7167 \qquad (5).$$

The influence of MC is stronger in higher order natural frequencies. The influence of temperature is relatively low, but not totally negligible. For example, an extreme temperature change of 30 °C induces the change of 4th natural frequency of about 4 Hz. General declaration of parametric models allows changes in design, material composition, etc., enabling the deployment of optimization calculations, study of factors' influence on the behavior of the board. In terms of FEM, use of different mesh, software capabilities, model assumptions and simplifications were studied.

Acknowledgements

Research proceeds in cooperation with the company Petrof Ltd., Czech Republic.

Bibliography

Berthaut, J., Ichchou, M. N., Jézéquel, L., Piano soundboard: Structural behavior, numerical and experimental study in the modal range. *Applied Acoustics*, 64(11): 1113-1136, 2003.

Boutillon, X. Model for piano hammers: Experimental determination and digital simulation, *J.Acoust.Soc.Am.* 83(2):746-754, 1988.

Bucur, V., *Acoustics of wood*. 1st Ed. CRC Press Inc., NY, 284 pp., 1995.

Chaigne, A., Askenfelt, A. Numerical simulation of piano strings. I. A physical model for a struck string using finite difference methods, *J.Acoust.Soc.Am.*, 95: 1112-1118, 1994.

Cuenca, J., Causse, R., Three-dimensional interaction between strings, bridge and soundboard in modern piano's treble range. In *Proceedings of the 19th International congress on acoustics*, Spain, 2007.

Giordano, N., Jiang, M., Physical Modelling of the Piano. EURASIP *Journal on Applied Signal Processing*: 926-933, 2004.

Hall, D. E., Piano string excitation VI: Nonlinear modelling, *J.Acoust.Soc.Am.* 92: 95-105, 1992.

Hashimoto, T., Umetani, Y., Numerical Simulation of Piano Sounds. Toward the Combined Analysis of Strings, Bridge and Soundboard. *IEIC Technical Report*, 99(626): 1-6, 2000.

Mamou-Mani, A., Frelat, J., Besnainou, C., Numerical simulation of a piano soundboard under downbearing. *Journal of the Acoustical Society of America,* 123(4):2401-2406, 2008.

Ortiz-Berenguer, L. I., Casajus-Quiros, F. J., Blanco-Martin, E., Ibanez-Cuenca, D., Modelling of piano sounds using FEM simulation of soundboard vibration. *Proceedings of Acoustics'08* Paris, 2008.

Požgaj, A., Chovanec, D., Kurjatko, S., Babiak, M., *Štruktúra a vlastnosti dreva*. Bratislava, Príroda, 488 p., 1997.

Siau, J.F., *Wood. Influence of moisture on physical properties*, NY Virginia Polytechnic Institute and State University, 227 p., 1995.

Skaar, C. H., *Wood-Water Relations*, Berlin Heidelberg, Springer-Verlag, 283 p., 1988.

Suzuki, H., Nakamura, I., Acoustic of piano. *Appl. Acoust.* 30:147-205, 1990.

Experimental Investigation of a Non-Invasive Intervention on a Torres Guitar

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Introduction

Guitar FE09 - MDMB 626 is one of the best-known Antonio de Torres instruments and is an excellent sounding example of a guitar with tornavoz. Tornavoz is a sound-hole tube for lowering the first resonance mode to improve the low-frequency response of the instrument [Hess, 2013]. Although the instrument is in "playable condition", the back plate has a deformation and cracks which are undoubtedly the result of the pressure exerted by the tornavoz supports (see Fig. 1). This instrument belonged to the guitarist and composer Miguel Llobet (1878-1938) who concertised and recorded with it and it was said to be his favourite of the 40 guitars he possessed. When he acquired the guitar around 1916 it already had the cracks caused by the pressure of the tornavoz sound-posts [Romanillos, 1997]. Furthermore, it is known that Llobet chose not to have the cracks repaired, as he feared it might result in a change in the sound.

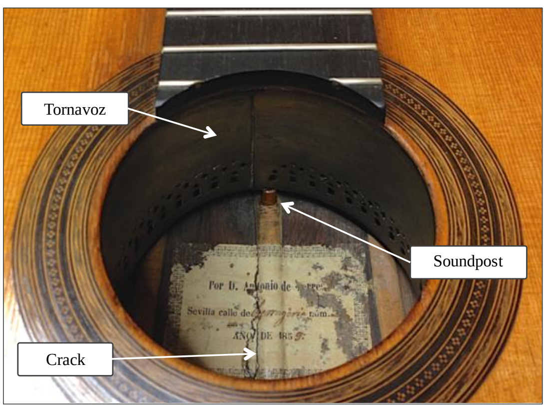

Figure 1: Detail of the sound-hole and tornavoz supported by wooden soundposts resting on the back.

Over the last hundred years experts have chosen not to have the cracks repaired as it might result in a change in the sound. In 2010 a new restoration was carried out by Luca Waldner, but access to the inside of the guitar is very limited and once again it was explicitly decided not to repair the cracks, respecting in turn the unwillingness of Llobet. On the occasion of a recent recording by the guitarist Stefano Grondona, he stated that guitar sounded different with strips of masking tape covering the cracks, something which the restorer also suggested. This observation was in general agreement with informal listening tests performed during the recordings. Although subjective evaluations and claims abound, no quantitative data is available to determine the effect of this modification. This paper provides the results of an experimental campaign aimed at assessing the effect upon the vibration response of this eventual non-invasive intervention.

Experimental method

Modal testing was performed on the top and back plates before and after adhering strips of masking tape along the cracks. An undulated foam surface was employed to reproduce controllable and repeatable boundary conditions (see Fig. 2). The vibration signals were measured and recorded as time series and processed into inertance FRF data. A mono-axial accelerometer was attached with beeswax to a reference point on the top plate near the bridge location, whereas the miniature rubber hammer transducer roved around exciting the board at 119 locations on the top and at 162 points on the back, both evenly distributed.

Figure 2: Assembly made for modal testing.

Results and conclusions

Two experimental approaches were addressed, the modal and the frequency domain correlation. The former provides correlation data of individual modal parameters but presents the main drawback of being dependent on user intervention since it requires significant post-measurement analysis. In contrast, the latter merges the correlation of multiple parameter shifts, but has the advantage of not being user dependent, thus becoming a promising, powerful and attractive tool for nondestructive evaluation. Results allow conclusions to be drawn regarding the influence of the intervention. In comparing the frequencies and quality factors (see Table 1), significant changes appear. With respect to the back plate, estimated modal frequencies increase, the differences being larger for the crack mode and higher frequency modes, where the modes are associated with local responses. In contrast, quality factors decrease, leading to an increase of damping. The hypothesis behind this observation is that strips of masking tape cause a slight increase in the stiffness of the back plate, limiting its mobility and thus increasing the modal frequencies (see Fig. 3). This argument agrees with the results obtained from the FRFs. Comparison of the vibration responses of the modified back plate with the baseline response reveals a decrease in the amplitude response level together with a widening of the peak bandwidth. This leads to an increase in damping whereby the quality factors decrease; a feature that is generally viewed as not desirable in musical instruments.

Lower incidence was observed on the top plate with the exception of the low frequency mode. Overall, with the exception of the first mode, frequency shifts are below the audible range and their associated quality factors do not show a conclusive behaviour. A major variation is observed in the fundamental mode which decreases around 2% and significantly increases its quality factor. The hypothesis behind this result is that strips of masking tape close the airflow

	Back		Modified Back		Difference		
Mode	f [Hz]	Q	f [Hz]	Q	Δf [%]	*Cents*	ΔQ [%]
RB	88.7	23.3	88.7	22.1	-0.1	-2.6	-5.1
Crack	128.9	19.2	138.2	14.9	7.2	119.6	-21.8
$1_{(b)}$	223.3	20.4	227.9	18.2	2.1	35.6	-10.7
$2_{(b)}$	246.7	35.6	250.8	26.0	1.7	29.1	-27.0
$3_{(b)}$	292.9	28.7	298.9	21.6	2.1	35.5	-24.8
$4_{(b)}$	333.8	38.0	337.9	24.4	1.2	20.9	-35.7
$5_{(b)}$	355.7	28.7	379.2	22.8	6.6	110.9	-20.4
$6_{(b)}$	382.3	28.7	392.7	24.1	2.7	46.4	-16.2
$7_{(b)}$	403.8	26.3	420.9	18.8	4.2	71.7	-28.4
$8_{(b)}$	441.0	43.6	464.7	23.6	5.4	90.7	-45.9
$9_{(b)}$	500.2	61.3	509.8	40.8	1.9	32.8	-33.5

Table 1: Modal parameters of back plate (muted-strings) before and after placing strips of masking tape covering the cracks.

through crack on the back. Assuming that fluid acts as an added mass, it is straightforward to prove that it has the effect of decreasing the frequency. This could lead to an increase in the coupling of the plates and thus to an increase in the amplitude response level. This remark agrees with the results obtained from the FRFs. Furthermore, a narrowing of the peak bandwidth is observed, leading to a decrease in damping and a quality factor increase.

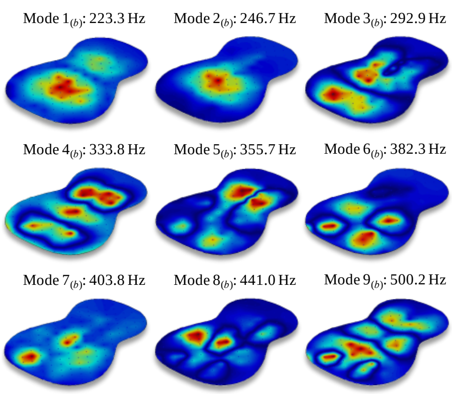

Figure 3: Experimentally determined resonance mode shapes of back plate before placing strips of masking tape covering the cracks.

The complete restoration of the instrument comes into question depending on whether the guitar is considered as a musical instrument rather than a cultural heritage oeuvre. There is no doubt that the instrument in its pristine state had no cracks. However, the design configuration employing the soundpost is particularly prone to crack even after restoration. Consequently, according to the musical purpose, the original structural configuration should eventually be re-adapted by removing the soundpost and unavoidably installing a transverse bar on the top plate. The consequences of this high impact intervention from the cultural heritage perspective are obvious.

Acknowledgements

The authors are very grateful to Oriol Rossinyol, Manel Barcons and Esther Fernández from Museu de la Música de Barcelona for their invaluable support and collaboration on this work. Special thanks also to Nil Górriz for his help during the measurements.

Bibliography

D. P. Hess, Frequency Response Evaluation of Acoustic Guitar Modifications, *Savart J.* 1–8, 2013.

J. L. Romanillos, *Antonio De Torres: Guitar-Maker His Life and Work*, Bold Strummer Ltd, 1997.

3D Emendatio: Digital Improvement and Printing of Musical Instruments

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Introduction

The main objective of the Industrial Design faculty at Delft University of Technology is to design and improve user defined products, and develop workflows for customizable products. In recent years, 3D printing techniques (also known as Additive Manufacturing) have been increasingly adopted for this aim, and TU Delft has gained a world-leading experience in the use and development of such techniques [1, 2]. These techniques have been recently applied for the manufacturing of saxophone mouthpieces [4], in a project that involved aerodynamic researchers at the Aerodynamic Department of the TU Delft Aerospace Faculty [3]. The aim of the project is to develop and improve the design of the musical instrument's parts, to provide novel strategies for the preservation of cultural heritage, and to comply with the requirements of musicians.

Preservation of cultural heritage

- Historical musical instruments that are currently played are subject to wear and will irremediably be lost over time.
- Other unique (original) instruments are kept safe (for the sake of preservation) and are therefore out of reach for musicians and the community.

Musicians' requirements

Musicians often have the need to explore new sounds by modifying their instrument (or part of it) in order to find the set-up that best fits them in terms of sound and playability.

- The research is often expensive and based on available items in the market, with little room for personalization.
- On the other hand, some musicians request handcrafted parts by specialized manufacturers that involve very high costs and low repeatability. Furthermore, the standard of manufacturing techniques entail waiting times of 4-8 weeks.
- In other cases, musicians use vintage parts that are usually expensive and unique. When these items are lost or damaged it is not possible to replace them, and it is hard for the musician to find a valid alternative.

Proposed methodology

At present, 3D printing is gaining interest whilst it is improving in terms of speed, quality, and price; it is becoming more accessible. Developments in digital manufacturing allow the production of complex geometries at a relatively low cost.

To address the problems described above, we have proposed and initiated a three-fold approach: “Translatio – Imitatio – Emendatio”. At the core of this approach is a continuously expanding digital repository of saxophone mouthpieces. In later stages the content of this repository can be expanded to other instruments as well.

Translatio

The "translation" element of the repository focuses on digitization, preservation and curacy. A key part of the activity is to obtain original mouthpieces and go through the process of 3D scanning, processing and digitalization of the scanned data in order to make it suitable for 3D printing. Owners of unique or historical pieces, but also mouthpiece makers, will be able to submit a mouthpiece for 3D scanning and digitizing. In this case, the repository provides an opportunity to archive and preserve the cultural heritage (the unique mouthpiece), while the owner of the mouthpiece is able to obtain a 3D printed copy of this mouthpiece, fabricated on demand.

Imitatio

The "imitatio" element of the repository makes currently unavailable mouthpieces available to musicians worldwide. If the IP status of the originally scanned mouthpiece allows, some mouthpieces within the repository can be made available for purchase by consumers (who are not owners of the original piece). In that case, customization of specific elements of the mouthpiece, such as the tip opening, becomes essential. In order to facilitate customization, the mouthpiece needs to be completely reverse engineered. This step includes making a parameterized 3D file based on the 3D scanning with a variable tip opening and eventually chamber size.

On the consumer side, the musician is provided with an (online) interface where he can make a selection form different mouthpieces and tip-openings. Once an order is placed, the specific geometry generated from the parametric model and the mouthpiece is fabricated and shipped.

Emendatio

The "emendatio" element of the repository is a platform for improving existing mouthpieces, going beyond what is possible in traditional manufacturing and utilizing the benefits of 3D printing. Using the knowledge from user testing and aero-acoustic measurements, we aim at optimizing the sound and playability of the mouthpieces. The goal is to be able to create geometrical modifications to match the player's requirements. This can yield completely new mouthpieces with novel internal geometries that utilize the benefits of 3D printing.

"Emendatio" requires the development of a more elaborate interface for the consumer, where the musician can input his requirements and preferences in terms of style, sound, and playability. This input data then needs to be translated into the final mouthpiece geometry before it is 3D printed and shipped.

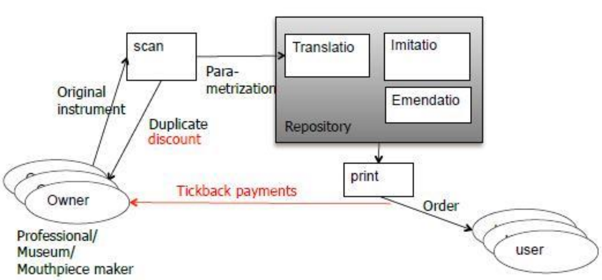

Figure 1: Schematic of model with generation of the repository.

This three-tier repository can be framed in an ecosystem in which mouthpiece owners can send in their original mouthpiece, which is then reverse engineered to be part of the repository. If the owners are the original mouthpiece makers, we offer tickback payments, effectively creating an "app store" model in which we ensure the quality of the reverse engineering and printing, while their reputation and fame is tied to a specific mouthpiece design. A similar arrangement can be made with museums that have a large collection of original saxophone parts in depot (for example: the museum "La Maison de Monsieur Sax", Dinant, and "Cité de la musique", Paris).

Application

The generation of the digital repository at TU Delft has already started in 2012 and several mouthpieces have been digitalized by the team. Variations and improvements have been made to the basic design according to musicians' requests and the results of the aerodynamic experiments described in [4]. The authors have successfully shown the newly designed mouthpieces at the North Sea Jazz festival 2012, with a positive feedback from musicians and manufactures. Professional musicians, Joure Pukl (NY) and ArtVark (NL), are still performing daily on them. Experiments have recently been carried out at the University of Music and Performing Arts in Vienna on a panel of mouthpiece designs to quantify the difference in radiated sound and ease of play. The results will be presented at the Third Vienna Talk on Music Acoustics, 16–19 Sept. 2015

Acknowledgements

Special thanks are given to Sandra Carral and Alex Hofmann of the University of Vienna for carrying out the experiments on some of our mouthpiece designs.

Bibliography

E. Doubrovski, J. Verlinden, and J. Geraedts, "Optimal design for additive manufacturing: Opportunities and challenges," in *ASME ETC2011*, vol. 4, 2011,pp. 112–124.

E. Doubrovski, J. Verlinden, J. Geraedts, I. Horvatha, and K. V.L.M., "Acoustic investigation of novel saxophone mouthpiece design," in *TMCE*, vol. 1, 2012, pp. 1–8.

V. Lorenzoni and D.Ragni, "Experimental investigation of the flow inside a saxophone mouthpiece by particle image velocimetry," *Journal of the Acoustic Society of America*, vol. 131, pp. 715–721, 2012.

V.Lorenzoni, Z. Doubrovski, J.Verlinden, "Embracing the Digital in Instrument Making: towards a Musician-tailored Mouthpiece by 3D Printing". *Proceeding of the ISMA conference Stockholm 2013*.

Acoustical Performance of Original and Replica Baroque and Classical Bassoons: Design and Coupling of Contemporary Bocals and Reeds.

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Background

In our recent study of original and replica Baroque and Classical bassoons (93 original, 17 replicas and 44 redesigned bassoons) we optimized the acoustic lengths of 13 fingerings (Bflat1-F3). [Hichwa, 2015] The optimized results deduced from this acoustic model include 1) acoustic length (AL) of bocal + bocal extension, 2) Benade adjacent tone-hole position correction, 3) Hichwa-Benade 2nd adjacent tone-hole position correction, 4) 180° boot-joint turn around correction of large bore notes (Bflat1-G2), 5) bell correction to C2 tone-hole. This non-linear acoustic model has now been combined with an impedance model to better understand the drivers to improve the bassoon acoustic system.

Bocals

One of the major issues confronting researchers attempting to model historical bassoons is the lack of original bocals and reeds. Our initial model calculated the acoustic lengths relative to the top of the Wing Joint (WJ), giving a combined length of the bocal and bocal extension. A more complete acoustical impedance (Z) approach now provides a mechanism to evaluate specific bocals and reeds. Our segment program incorporates the measurements of 110 bassoons and builds the entire instrument for the impedance program including the bocal and a multi-segment reed. The impedance program calculates the experimental values of the harmonics for 30 fingerings (Bflat1-G4) and compares these results with the theoretical values.

We attempted to measure the inside diameters of original bocals, but found the data to be inconsistent. We identified 26 period bocals designed to be played on replicas of Baroque and Classical bassoons. Period bassoon makers' ability to design and fabricate these replica bocals proved crucial in this analysis.

Reeds

Our calculation of the "playing" state reed volume is likewise critical to the analysis. We designed a reed model with seven adjustable shape parameters to match the volume of the missing bocal extension. These adjustable parameters have implications for the player of replica bassoons since each player's approach to embouchure is different.

Bassoon Name	# of Originals Analyzed	# of Replicas Analyzed
Eichentopf	3	4
Grenser A	6	2
Grenser H	7	1
Porthaux	9	0
Prudent	5	3
Scherer	2	3

Table 1: Representative # of Original and Replica Bassoons Analysed

Impedance Calculation Results

For each fingering (BFlat1-G4), we combine the position (frequency) and magnitude of the impedance peaks. The results were incorporated according to the method of Grothe. [Grothe, 2014] Typically, 4-6 harmonics were included for the lower frequencies prior to the onset of the cut-off frequency, while for the higher frequencies, 2-4 harmonics dominate prior to the cut-off. The database size allows extraction of statistically meaningful results. This is especially meaningful when multiple bassoons fabricated by the same original maker are compared and contrasted with replicas as seen in Table1.

In our presentation we will also demonstrate that changes in coupling (bocal shape, length and initial diameter) between the WJ and bocal enhances acoustic performance. The result is an in-depth fundamental understanding of historical bassoon acoustics which in turn can be used to fabricate an improved acoustic system on replica period bassoons.

Bibliography

Grothe T., *Experimental Investigation of Bassoon Acoustics*, Dr.-Ing diss., Fakultat Maschinenwesen der Technischen Universitat Dresden, 129-130, 2014.

Hichwa, B. and Rachor D., 'Study to Optimize Acoustical Performance of Original Baroque and Classical Bassoons', Galpin Society Conference, 2015.

The Next Generation Concert Piano

Chris Maene (Piano Builder, Belgium), Wolf Leye (Belgium)

Introduction

The modern concert piano is not the result of an evolution from primitive to perfect, but rather a product of change that has followed the evolution of the composers. From its invention around 1700 and further development until 1900, there were many different highlights in piano manufacturing that coincided with the great composers. If we take into account the evolution of piano manufacturing and the music that has been written for these instruments, we can distinguish three types/highlights:

- Early, ca. 1650-1810 (Scarlatti, Bach, Mozart, Haydn, etc.)
- Middle, until ca. 1840 (Schubert, Chopin, Liszt, etc.)
- Late, until ca. 1900 (Brahms, Schumann, Debussy, etc.)

Nowadays all this music is being played on the same type of instrument: the modern concert piano. But since the beginning of the 20th century, the piano has become increasingly standardized (in particular after the model of Steinway). This standardization of sound results in an impoverishment of sound diversity. Today, almost every piano on a concert stage shows the same main characteristics. At the same time, we notice that pianists today are mainly playing music from before 1900 (music from Bach to late romance, 1685 – 1900). A modern concert grand is an anachronism in the performance of this music. In response to this growing impoverishment, pianists are looking for alternatives. And so, from the 1950s, some musicians started playing on historic instruments (originals and copies). But these instruments are not always easily accessible and/or available, demanding a different approach to maintenance and playing technique, and concert halls are often not build to suit their volume. As a result, not all pianists see these historic instruments as a good solution/alternative.

From this situation came the wish to build a new concert piano, based on historic keyboards, but with the comfort (action, touch, volume, transport convenience) of a modern piano. To realise this we went go back to the principle of the straight strung piano (the strings of the bass are not crossed over the treble strings, they are parallel with them). This results in a sound which is not homogeneous (like with cross stringing), but a sound with three "registers": bas, medium, treble. In 2014-2015 we already made a first modern straight strung piano, commissioned by and in cooperation with pianist-conductor Maestro Daniël Bärenboim. The objective is to build 3 concert pianos on which 3 centuries of piano music can be played, taking into account the sound colour from the corresponding periods.

Methods

First we examined how piano manufacturing has evolved, what the technical characteristics are of piano manufacturers in the past, etc. Therefore, we made an analysis of 25 historic concert pianos on the basis of:

- The string plan (string lengths, thickness, striking point, tension, breaking point, etc.)
- The frame (design, placement, casting method)
- The soundboard (thickness, ribs, wood, grain direction, etc.)

- The case (shape, reinforcement beams, wood)
- Keyboard and action (the relation of the components, the size and weight of the hammerheads)

Results

The first modern instrument with straight stringing from the experiment with Maestro Daniel Bärenboim has already been finished. The results are visible and audible. In April 2017 new straight strung concert grand pianos were finished. Currently many world class pianists (Pierre Laurent Aimart, Kristian Bezuidenhout, Frank Braley, Hannes Minnaar, etc.) are discovering the new piano and using the instruments for concerts and recordings. Their response on the piano has been documented with video recordings and is accessible via following link:

https://www.youtube.com/channel/UCYT4xSD0lkXt8iOLqcrC77A

Further research is still in progress for the manufacturing of the other models. By the beginning of 2018 a chamber music grand piano will also be available.

www.chrismaene.be

Perceptual Study of Touch on a Pleyel Piano from the Collection of the Paris Museum of Music

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Introduction

The Pleyel piano E.991.16.1 (Inv. No.) from the collection of the Paris Museum of Music was made in 1842 [Pleyel, 1842]. It is an archetype of the romantic piano built by the Pleyel firm in the nineteenth century. This instrument was acquired with all its original parts (keyboard, hammers, strings, soundboard, etc.). However, a facsimile of the hammers was produced in 2005, at the museum's request, to make the piano usable for concerts and recordings [Stern, 2010]. The restoration work has raised some problems inherent to the patrimonial status of this instrument: conservation and preservation of authenticity, from both the making processes and sonic potential points of view, were considered very carefully. Later, the laboratory of the Museum undertook mechanical engineering studies on original and facsimile hammers. Wood density measurements showed some differences. It was then decided to choose more similar woods and plan another restoration work. A second facsimile was ordered in 2014 from the French piano maker Maurice Rousteau. To find out if this modification was relevant, a perceptual study was set up with fortepianists who were invited to express their feelings while playing this piano. So, our study was based on a multidisciplinary approach (mechanical engineering, sensory analysis, linguistics analysis and musicology) in order to improve the knowledge of the instrument, as well as practices and expectations of musicians.

Figure 1: New hammers of the Pleyel piano E.991.16.1 from 1842 (collection of the Paris Museum of Music). Facsimile made in 2014 by the French piano maker Maurice Rousteau.

Interviews management

Nine pianists participated in the study. The interviews, which lasted about 1 hour 30 minutes each, took place in a well-lit room, usually used for rehearsals and tuning of the museum instruments. Pianists were invited to come for two or three sessions (depending on their availability). The purpose of the study was explained to the musicians only at the end of the last session, so as not to influence their assessments. The tuning of the piano was checked before each session and some settings were made according to Claude Montal's recommendations book [Montal, 1865]. The musicians first played the instrument freely. Then, they had to talk about their own evaluation criteria for such a piano and provide the definition of each specific word they used to describe it [Navarret, 2013][Paté, 2014]. Next, they were asked to perform two works of the repertoire (one imposed, and the other at the choice of the pianist) and play the total chromatic scale with the eighty notes of the keyboard for subsequent studies that the laboratory could lead.

Figure 2: "Salle d'harmonisation". Room of the Paris Museum of Music where the interviews of nine fortepianists took place in 2014.

Verbal data analysis

The sessions were recorded to constitute a corpus of sound samples and to make the transcription of the interviews. The processing of verbal data analysis was based on a semantic analysis [Cheminée, 2009][Dubois, 2009] of several complementary corpus: evaluation criteria of musicians, vocabulary definitions, feelings expressed about the Pleyel piano from 1842, shared knowledge about Erard and Pleyel pianos (which were two famous firms in competition in the nineteenth century) and musical repertoires.

Results

Four evaluation criteria were common to all pianists: sonic properties of each musical range, the key action mechanism, dynamics and pedal response. In addition, the romantic Pleyel piano was described as very different from the modern piano in terms of touch (because of the action mechanism), heterogeneity of ranges (they said that modern pianos were more homogeneous from low to high notes) and dynamics response (the threshold of "saturation" of a romantic piano was lower than that of a modern piano). Furthermore, some musicians and piano makers previously described the touch of this Pleyel piano as relatively heavy. So, the main purpose of the study was to verify this hypothesis. The study showed that musicians did not use the term "heavy touch". However they were sensitive to various properties of the keyboard touch (or the key action mechanism). Thus comments on "the attention to pay to the articulation of the musical phrasing", "latency between key release and fall of the hammer" or "the difficulties to control soft nuances" might be in relation to the sensation of heaviness. Of course, they said this piano was well suited to compositions by Frédéric Chopin (1810-1849), but more broadly, to works with high differentiated ranges.

Discussion

A more thorough analysis of verbal data has to be done. For instance, we have to continue the semantic analysis of the pianists' vocabulary and the comparison of discourses about facsimile hammers. However, first results showed musicians' expectations and how they used to evaluate this type of piano. It gave an accurate description of the sound rendering of the Pleyel piano E.991.16.1 in the museum's collection, and yielded an extensive corpus of verbal data and recordings for further studies.

Acknowledgements

I would like to thank Maurice Rousteau for the entire restoration work and the maintenance of this piano; the nine fortepianists who so generously participated in the study: Joanna Choi, Mathieu Dupouy, Jean-Sébastien Dureau, Knut Jacques, Luca Montebugnoli, Aya Okuyama, Soo-Hyun Park, Alain Planès and Natalia Valentin; Stéphane Vaiedelich and Sandie Le Conte for entrusting me with this mission; Jean-Claude Battault and Thierry Maniguet for logistical support and contribution to the elaboration of the experimental protocol; Emmanuelle Audouard, Delphine Delaby and Daria Fadeeva for musicians contact.

Bibliography

Cheminée Pascale, "Est-ce bien "clair" ? Stabilité, instabilité et polysémie d'une forme lexicale en contexte" in *Le Sentir et le Dire, Concepts et méthodes en psychologie et linguistique cognitives*, Ed. L'Harmattan, Paris, 309-338, 2009.

Dubois Danièle et al., *Le Sentir et le Dire, Concepts et méthodes en psychologie et linguistique cognitives*, Coll. Sciences cognitives, Ed. L'Harmattan, Paris, 2009.

Montal Claude, *L'Art d'accorder soi-même son piano : d'après une méthode sûre, simple et facile, déduite des principes exacts de l'acoustique et de l'harmonie*, Ed. Messonnier, Paris, 1865.

Navarret Benoît, *Caractériser la guitare électrique : définitions, organologie et analyse de données verbales*, PhD thesis, Paris 8 University, Vincennes/Saint-Denis, 2013.

Paté Arthur, *Lutherie de la guitare électrique solid body: aspects mécaniques et perceptifs*, PhD thesis, Pierre et Marie Curie University, Paris, 2014.

Pleyel piano from 1842 (Inv. No. E.991.16.1), Paris Museum of Music data sheet: http://mediatheque.cite-musique.fr/masc/?INSTANCE=CITEMUSIQUE&URL=
/MediaComposite/CMFM/CMFM000001500/default.htm

Edna Stern, *Chopin*, compact disc, Ed. Naïve-Cité de la musique, Paris, 2010.